Installation of monitoring well MMW022 at Henry Mine

P4 PRODUCTION

INTERIM REPORT FOR HYDROGEOLOGIC INVESTIGATION
Revision 3

2007 HYDROGEOLOGIC DATA COLLECTION ACTIVITIES AND UPDATED CONCEPTUAL MODELS

Prepared by

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1.0 INTRODUCTION

This report is being submitted as a deliverable for work under the Consent Order/Administrative Order on Consent for the Performance of Site Investigations and Engineering Evaluations/ Cost Analysis (EE/CAs) at P4 Production, L.L.C. Phosphate Mine Sites in Southeastern Idaho (08/20/03), EPA Docket No. CERCLA-10-2003-0117.

This report documents the results of the Phase IIa Groundwater Investigation conducted at the P4 Production, LLC (P4) inactive Ballard, Henry and Enoch Valley mines (Drawing 1). The contents of this document focus on the data developed during field activities conducted in 2007, and on the presentation of updated conceptual hydrogeological models of the mine areas. The hydrogeologic investigation is in progress and this report is presenting interim and preliminary data and evaluations. Validation of all data presented in this report from 2006 and 2007 has not been finalized; therefore, the data are considered preliminary. This includes both the chemical and geological data. Similarly, the conceptual models presented are working models and will continue to be revised as new data or interpretations are developed.

1.1 PROJECT DESCRIPTION AND OBJECTIVES

The basis for the work conducted in 2007 is the Monitoring Well Installation Technical Memorandum (MWH, 2007a) which was presented in fulfillment of Activity 3b-5 of the Final 2005 Phase II Supplemental SI Work Plan (MWH, 2005) (Phase II Groundwater Work Plan). The Phase II Groundwater Work Plan is an addendum to the P4 Production Southeast Idaho Mine-Specific Selenium Program 2004 Comprehensive Site Investigation Final Work Plans for Ballard, Henry and Enoch Valley Mines (MWH, 2004) (2004 SI Work Plan). The Phase I groundwater investigation tasks were set forth in the 2004 SI Work Plan and were initiated in 2004. The Phase I and Phase II groundwater investigations are being conducted in accordance with the requirements of the AOC signed by P4 Production, IDEQ, United States Environmental Protection Agency (USEPA), and United States Forest Service (USFS). This work supports the comprehensive mine-specific site investigations.

The purpose of the groundwater investigation is to identify groundwater flow systems that are contaminated by waste rock sources at the historic P4 mines, and to characterize the nature and significant extent of such contamination and the risk associated with it. This investigation is conducted in a phased approach, such that initial phases of work focus on information gathering and development of site hydrogeologic conceptual models. Phase I work incorporated gathering easily accessible chemical data from the sampling of seeps, springs and existing groundwater wells to identify specific areas of interest and areas in need of further investigation. The Phase II program is focused on collecting new data to specifically characterize groundwater flow and potential impacts associated with the mine areas. This includes installation of new groundwater monitoring wells. To date, the Phase II program has resulted in the installation of 16 monitoring wells and additional water quality data collection.

The specific objectives of this document include the presentation of data collected in 2007 to P4, and the Agencies and Tribes (the Agencies). The 2007 Monitoring Well Installation Technical Memorandum (MWH, 2007a) contained data through 2005. Data from 2006 was submitted to the Agencies in the 2006 Data Validation Report. This objective is addressed in Section 2. As mentioned above, the data are preliminary and are subject to finalization through the data validation process. However, the preliminary data are presented in this interim report to help facilitate timely discussion and development of the next stage of the Phase II groundwater investigation to be implemented during the 2008 field season (Phase IIb). This document does not present the comprehensive data and background information for the overall project. This information is contained in previously submitted documents, including the Monitoring Well Installation Technical Memorandum (MWH, 2007a).

An additional objective of this document is to present P4 and the Agencies updated and refined conceptual hydrogeologic models of the mine areas. The presentation of the conceptual models, included in Section 3, is largely provided to address the Data Gap Memorandum presented to P4 by the Agencies and the subsequent correspondences including P4 Production's and the Agencies' responses to the original document (IDEQ, 2007a, and IDEQ, 2007b). Regardless of the data gap memorandum, this process is key to the development of the next phase of investigation. The refinement of the conceptual models is based on the data collected in 2007 presented herein, and on further detailed analysis of existing data (e.g., dissertations and theses), and on a general increase in the knowledge gained from combining these two sources of information. This process will be repeated at the end of the next round of field activities for inclusion in the final report or to support the next phase of investigation.

As part of this report, general recommendations for the 2008 field program are presented in Section 3 and summarized in Section 4. This suggested work is conceptual at this time. A technical memorandum will be presented to the Agencies detailing the planned 2008 activities and procedures. In addition, the Direct-Push Work Plan (MWH, 2007b) has been presented in draft form, reviewed by the Agencies, revised and resubmitted, and is currently being reviewed by the Agencies a second time. This plan will be implemented in 2008 and addresses many of the data needs summarized herein.

1.2 PROJECT BACKGROUND AND SETTING

This document does not present an extensive discussion of the background of the mine sites or the geologic and hydrogeologic setting. This information has been provided in the preceding technical memorandum (MWH, 2007a), and is also available in other published documents (e.g., Ralston, et al., 1980). However, because this document focuses on the hydrogeologic systems and potential impacts to those systems, some introductory material is helpful and is presented in the following sections. The reclamation practices used at the three mines also are an important consideration when evaluating the potential impacts to groundwater, and these practices need to be considered when evaluating the data. Therefore, a discussion of these practices is also presented in this section. In addition, a challenging portion of this project has been the integration of various maps from as far back as 1927 into a usable database. Improvements have been made in 2007 to improve the accuracy and level of detail of the mapping database. Some background on this database is also provided at the end of this section.

1.2.1 Hydrogeology

Groundwater in the region can be divided into local shallow groundwater within basin-fill alluvium and shallow to deep intermediate and regional groundwater flow systems within sedimentary bedrock units. The alluvium and colluvium in the valleys is up to 150 feet thick and recharged by direct precipitation and shallow flow from the topographic ridges. Alluvial groundwater systems interact directly with the local surface water systems along the valleys with gaining and losing streams at different locations. Where the bedrock sedimentary units contact alluvium, groundwater will similarly move between the bedrock and alluvium depending on the hydraulic characteristics of the units and the hydraulic gradients at different locations. Due to this interaction, the alluvial groundwater is generally unconfined and the water table surface and groundwater flow generally mirrors surface topography and surface water flow directions.

Recharge to the bedrock units generally occurs along outcrops, particularly along topographically high ridges and flows downward, typically along the dip of the geologic beds. Groundwater flow through bedrock units is controlled by several factors including the hydraulic properties of the units (i.e., with bedding and cross bedding hydraulic conductivities) and hydraulic gradients, the areal extent, thickness and orientation of the geologic units, as well as structural controls such as folding, fracturing and faulting. Fracturing of bedrock rock units (especially chert and limestone) has the potential to create secondary permeability and increase the hydraulic conductivity in an otherwise low-conductivity unit.

As an example of structurally developed secondary permeability, moderate groundwater yield is possible from the Rex Chert Member of the Phosphoria Formation, which normally is a low permeability unit. The water yield in the Rex Chert is due to the tendency of the chert to exhibit brittle deformation behavior (more susceptible to fracturing when stressed). In certain stress fields the chert will shatter producing closely spaced open fractures. In a tectonic setting such as the one that produced the folding and faulting in the Monsanto mine areas, this may result in linear bands of fracturing parallel to fold axis and along thrust faults, for example. Subtle changes in the deformation stresses can result in significant changes in degree and character of fracturing and therefore permeability. This can also occur in other beds in the Phosphoria Formation and indeed any competent rock unit subjected to deformation. In general, these types of water bearing zones are not a target for groundwater production where other sources are present due to unpredictable results. Often high yields cannot be sustained because of limited extent of the fractured zone. Previous studies in the Idaho phosphate area have also indicated that spring discharge to surface water from the Phosphoria Formation is an infrequent occurrence (Winter, 1980; Ralston et al., 1980). Approximately 2% of spring discharge and total stream gain was found to be supplied by the Phosphoria Formation regionally (Winter, 1980).

The principal stratigraphic units in the program area range in age from Mississippian to Quaternary and are described in Table 1-1, *Generalized Stratigraphy of the Program Area*. The Thaynes, Dinwoody, Phosphoria, and Wells Formations are the principal sedimentary formations in the program area through which groundwater flow may occur. Previous hydrogeologic research conducted in the area generally indicates the following regarding potential bedrock groundwater systems in the area:

- The Thaynes and Dinwoody Formations typically support intermediate groundwater flow systems (Ralston et al., 1977; Ralston et al., 1980).

- The Phosphoria Formation does not support any major groundwater flow systems; however, the Rex Chert member may transmit groundwater where locally fractured (Ralston et al., 1977; Ralston et al., 1980). The main ore-bearing unit of the Phosphoria Formation, the Meade Peak Phosphatic Shale, is relatively impermeable due to low vertical hydraulic conductivity (McGregor, 1993; Ralston et al., 1980).

- The Wells Formation supports a regional groundwater system (Ralston et al., 1977; Ralston et al., 1980). The Wells Formation has the highest hydraulic conductivity compared to the other bedrock units in the region (BLM, 1999).

TABLE 1-1
GENERALIZED STRATIGRAPHY OF THE PROGRAM AREA [1]

AGE		FORMATION	MEMBERS	GENERAL DESCRIPTION	HYDROGEOLOGIC CHARACTERISTICS [2]
CENOZOIC	Quaternary	ALLUVIUM (Qal and Qw)	--	Alluvium or colluvium.	Supports local groundwater flow system.
	Quaternary/ Tertiary	BASALT (Qb)	--	Basalt flows, basalt ash.	Can support intermediate groundwater flow system where fractured.
MESOZOIC	Triassic	THAYNES (TRt)	Several Members	Mostly limestone with sandstone layers. Some siltstone and shale members.	Supports intermediate groundwater flow system.
		DINWOODY FM (TRd)	Upper Unit	Grey, fossiliferous limestone interbedded with olive-brown calcareous siltstone.	Supports intermediate groundwater flow system.
			Woodside Shale	Reddish-brown siltstone and shale. Discontinuous in program area.	Does not support groundwater flow system.
			Lower Unit	Olive-brown calcareous siltstone and shale with thin-bedded limestone.	Supports intermediate groundwater flow system.
PALEOZOIC	Permian	PHOSPHORIA FM (Pp)	Retort Phosphatic Shale	Phosphatic shale. Discontinuous in program area.	Does not support groundwater flow system. Low hydraulic conductivity layer.
			Cherty Shale	Thin-bedded dark-brown to black cherty mudstone, siliceous shale and argillaceous chert.	Does not support groundwater flow system. Low hydraulic conductivity layer.
			Rex Chert	Thick-bedded black to white chert with some mudstone and some limestone lenses.	May support groundwater flow where highly fractured in areas.
			Meade Peak Phosphatic Shale (Ppm)	Dark-brown to black mudstone, limestone and phosphorite. Meade Peak member is typically mined.	Does not support groundwater flow system. Low hydraulic conductivity layer.
	Permian/ Pennsylvanian	PARK CITY FM [3]	Grandeur Limestone	Light grey dolomite and cherty dolomite with some sandstone. Discontinuous in program area. Mapped with Wells Fm.	May support a flow system, but is not present throughout the project areas. It appears to be present at Ballard, but not Henry or Enoch Valley.
		WELLS FM (IPPw)	Upper Unit (IPPwu)	Light grey to reddish-brown sandstone, some interbedded limestone and dolomite.	Supports groundwater flow systems.
			Lower Unit (IPPl)	Medium bedded grey cherty limestone, some interbedded sandstone.	Supports groundwater flow systems.
	Mississippian	BRAZER OR MONROE CANYON FM (Mb)	Brazer Limestone	Light grey limestone with interbedded sandstone, occasionally with grey and green shale.	--

Notes:
1. Stratigraphy based on Ralston, et al., 1980 and Ralston, et al., 1983.
2. Notes on hydrologic characteristics are based on several sources of information. Information not available for all units.
3. Often mapped as part of the Wells Formation.

In general, the flow systems in the Thaynes and Dinwoody Formations are separated from the lower Wells Formation by the low hydraulic conductivity of the Phosphoria Formation (in particular the Meade Peak member). This causes the upper flow systems in the Thaynes and/or Dinwoody Formations to be local or intermediate in extent while the lower flow system in the Wells Formation may be more regional.

It should be noted that the above are generalities. For example, the Wells Formation could support local or intermediate systems, and the Dinwoody or Thaynes Formations could support local flow systems. However, the converse cases are generally not known (e.g., alluvium is unlikely to support a regional or intermediate flow system).

Any flow systems encountered in the Phosphoria Formation will not be regional in extent but could be intermediate or local in sporadic cases. It is most likely that where encountered in the Phosphoria Formation groundwater occurs in isolated structurally-controlled systems confined to specific beds or units. Regardless, flow through the Phosphoria Formation perpendicular to bedding is expected to be very limited due to the presence of shales and mudstones, which are less susceptible to structurally induced secondary permeability. The potential risk and associated potential groundwater contamination in this type of system is much less than in the more laterally extensive flow systems associated with the other bedrock units. As such, the current conceptual models and hydrogeologic investigations are not focused on flow within the Phosphoria Formation. However, if significantly contaminated groundwater is encountered in the adjoining bedrock systems, then potential Phosphoria Formation flow systems may need to be considered and evaluated. To date, the conditions have not been demonstrated that would warrant an investigation of the Phosphoria Formation as a flow system pathway.

1.2.2 Reclamation Practices

The historic mine reclamation practices may have a significant role in controlling the sources of selenium and other potential contaminants, and their release into the groundwater environment. In general, successful reclamation reduces visual impact and returns the land to a self-sustaining natural condition or other designed post-mine land use. In addition, where the mine wastes can contribute contaminants to the environment, it is often the objective to reduce contact between the mine wastes, air and water as to eliminate or reduce long-term impacts to groundwater, surface water and other environmental media. This is often accomplished by encouraging controlled stormwater runoff and the use of vegetation to transpire any infiltrating water and develop an organic layer that helps consume oxygen. Topsoil, from stockpiles, direct haul, or other growth media may be placed in a layer covering the waste rock to promote vegetation where the waste rock has unfavorable characteristics for vegetation. In the case of highly reactive or contaminated waste rock (e.g., those that generate acid-rock drainage), low permeability cover material and drainage layers may be used.

As the years have passed, reclamation practices at the P4 Production mines have become more sophisticated and effective in reducing infiltration and oxidation in the mine waste dumps. The Ballard mine is the oldest of the three mines being addressed by the hydrologic characterization program associated with this report. It was mined from 1952 to 1969. The Henry Mine was active between 1969 and 1989, and Enoch Valley Mine was active between 1989 and 2003. The Ballard Mine has been subjected to some reclamation, but not to the extent as what is seen at the Henry and Enoch Valley Mines.

The Ballard Mine was primarily mined by using scrapers, and there was no planned segregation of the material in the waste rock dumps or cover placement. Because of the mining sequence, unoxidized middle waste shales from the bottom of the mine pits typically ended up on the outer dump surfaces. There are several grasses and alfalfa that were planted on the mine waste rock areas that are doing well, but there are some angle of repose slopes where vegetation is not complete. In general, the tops of some of the dumps have not been graded to promote stormwater drainage, and the mine pits have not been backfilled and graded.

The Henry Mine was transitional between historical practices and more modern reclamation practices. Initially, the waste rock disposal practice was similar to the Ballard mine with external waste rock dumps. However as a result of some of the early reclamation research performed at Ballard together with influence of the Mine Reclamation Act of 1972, reclamation became a standard part of the mining practice at the Henry Mine. By 1978, backfilling mine pits also became a common practice. As a result, most of the mine pits have been backfilled and graded to promote stormwater drainage off of the pit backfill. Portions of the mine highwalls remain exposed in a number of the pit areas; however, these exposures are footwall Wells Formation limestone, not selenium-bearing rock. Only mine pits on the northern and southern ends of the mine were left un-filled. All of the mine waste areas have been successfully revegetated with generally excellent coverage. Grading of the mine waste areas is generally good, but some mine areas without adequate drainage are present. General practices at the Henry Mine included the use of oxidized brown shales as a cover over various dump materials, which has likely provided more favorable cover characteristics (e.g., lower permeability, higher water retention capacity resulting in increased plant growth and density).

The reclamation at the Enoch Valley Mine utilized modern practices with pit backfilling, slope grading and planned revegetation. Most reclaimed areas at Enoch Valley received either direct haul or stockpiled topsoil, with the exception of pit and external dump areas reclaimed prior to 1993 located at the extreme South and North ends of the Enoch Valley Mine area.

In general, the reclamation success at the discussed mine sites has improved through time with Ballard exhibiting the least effort in grading, seeding and resulting vegetative cover. In general Ballard was mined with little or no pre-mine reclamation planning. The reclamation at Ballard occurred strictly post-mining with incomplete grading and seeding. The Henry Mine exhibits a significant change in reclamation practice exhibiting some of the densest vegetation observed at the mine sites. The typical seed mixes at Henry Mine utilized a relatively limited selection of aggressive, introduced grasses and forbes planted generally in well oxidized center waste cover materials. The Enoch Valley Mine represents another evolution and improvement in reclamation practices. It began utilizing practices similar to Henry until 1993. After 1993, it evolved into utilizing topsoil cover exclusively, along with an increased diversity of native grasses and forbes in the seed mix. The result of this improvement is a slightly lower vegetative cover density compared to Henry but with more native species. This results in an increased opportunity for the pre-mining plant communities to re-establish through natural processes. Based on the reclamation efforts, it would be expected that the Henry and Enoch Valley Mines would have less potential for environmental impacts to groundwater and other media compared to the Ballard Mine.

1.3 MAP DATA AVAILABILITY AND USE

Geologic and topographic data for the project come from multiple sources with variable data quality and accuracy. Unfortunately, differences between the data sources have not been completely reconciled. This is further compounded because there are three topographic surfaces that are relevant: (1) pre-mine; (2) post-mine, which because of concurrent reclamation practice, includes pit backfills; and (3) the mine pit configuration/topography. The geologic sections presented to help illustrate the conceptual models were constructed by “cutting” the section from the pre-mine topography then overlaying the post-mine and pit profiles when available. The geology was then hand-drawn on the sections based on the available geologic mapping, adjacent geologic sections, and geologic principles. The interpreted geology was then digitized onto the sections.

Because of the mixing of data sources of varying accuracy, the geologic sections and maps presented in this report should be considered conceptual and approximate. The geology, topography and mine features in plan view do not reconcile in some areas, and the hydrogeologic/geologic sections required some adjustment to present an accurate depiction of the hydrogeologic system at these locations. However, nowhere is the variability significant enough that the difference would change the interpretation of the hydrogeologic system or conceptual model. Listed below are the various data sources used to develop the maps, cross sections, and conceptual models.

Area-wide

- Regional Pre-mine Topography – USGS digital elevation model from Henry, Wayan West and lower Valley quadrangles – state plane coordinate system (SPCS) using NAD27 with 20 foot contours. The SPCS/NAD27 is used as the common base for the project.

- Regional Geology – Mansfield (1927). – Geology for the area was digitized from the hardcopy map. A scaling error is present that results in some misalignment of geology with known contacts. The source of the error is not known but may be related to the original mapping or the transfer of the map to digital form. This mapping is also regional in scope and may not be accurate at the local scale (e.g., small alluvial deposits are not generally shown).

Ballard Mine Area

- Post-mine Topography – P4 aerial mapping from 2005. This detailed mapping is in a mine-specific coordinate system that requires conversion to the SPCS/NAD27.

- Mine Pit Configurations – There is only very limited pit backfill, so post-mine topography generally depicts mine pit topography.

- Current Mine Waste Areas and Pit Outlines – From P4 aerial mapping.

- Mine Area Geology – Adapted from Mansfield (1927) and Hovland (1981). In this case, the detailed geology from Hovland (1981) was modified to be consistent with Mansfield (1927). This mostly consisted of using the unit subdivisions of the 1927 mapping. The details of the structural and lithologic contacts were retained from the Hovland (1981) mapping.

Henry Mine Area

- Post-mine Topography and Mine Pit Configurations – Available in hard copy only, and specific areas need to be researched in historic P4 reports. Some select areas have been digitized. Some topography and pit profiles are assumed.

- Mine Geology – Generally Mansfield (1927) is used; however, hardcopy company pre-mine geologic maps for the ore zone are available and have been digitized in small select areas. The ore zone geologic maps are limited to the ore zone and immediately adjacent geology.

- Current Mine Waste Areas and Pit Outlines – USGS Orthophotography from 2004 (1 meter ortho-rectified image).

Enoch Valley Mine

- Post-mine Topography – P4 electronic data periodically updated to show current status. The electronic data are in two separate mine coordinate systems for the northern and southern portion of the mine that require conversion to SPCS/NAD27. (With conversion some minor deviation in the USGS and P4 topography is present.)

- Mine-pit Configuration and Geology – Available from P4's electronic geologic model for the mine.

- Mine Geology – Generally Mansfield (1927) is used; however, detailed geology for the ore zone is available as needed from the P4 electronic geologic model (e.g., useful for siting well location near the mined area).

- Current Mine Waste Areas and Pit Outlines – USGS Orthophotography from 2004 (1 meter ortho-rectified image).

One significant addition to the map data base for the Ballard, Henry and Enoch Valley Mine areas in 2007 was the USGS topography containing the pre-mine conditions. This topography is shown on Drawing 1 for the general area. Drawings 2, 3 and 4 provide a smaller scale view with the mine features overlain for each of the three mines.

2.0 HYDROGEOLOGIC DATA FROM 2007 FIELD ACTIVITIES

2.1 SUMMARY OF HYDROGEOLOGIC FIELD PROGRAM

Hydrogeologic field activities included: drilling, installation, and development of new groundwater monitoring wells; borehole geophysics; soil and groundwater sampling and analysis; abandonment of existing groundwater well; and surveying well locations. Work was conducted in accordance with standard operating procedures included in the *Final Monitoring Well Installation Technical Memorandum Version 5a (MWITM)* (MWH 2007) submitted under the *Final 2005 Phase II Supplemental SI Groundwater Plan* (MWH 2005), and the *2004 SI Work Plan* (MWH 2004).

2.1.1 New Monitoring Wells

Sixteen new monitoring wells were installed at Enoch Valley, Henry, and Ballard Mine during the 2007 field season. Drilling, installation, and development of the new wells were done by Boart Longyear Co. A MWH field geologist observed, supervised, and documented the drilling and well completion activities, collected formation samples, and prepared geologic and well completion logs. An Atlas Copco TH-60 air-rotary rig was used to drill each boring. Clean water from the Enoch Valley Mine shop was added to the drilling air to suppress dust and facilitate drill cutting circulation. The supplemental water was turned off once the borehole began to make water.

2.1.2 Monitoring Well Abandonment

Wells MMW003, MMW005, MMW002 were abandoned during the 2007 field season. MMW003, at Henry Mine, was an open borehole and considered not suitable for monitoring. It has been replaced with new wells MMW011 and MMW019. MMW005, also at Henry mine, was 57 feet total depth but screened from 16 to 17.5 feet bgs and therefore, did not represent a useful groundwater monitoring point. MMW002, at Ballard Mine, was turbid and efforts to develop the well were not successful; therefore, it was replaced with MMW021.

Well MMW001 was proposed for abandonment in the MWITM (MWH 2007a); however, it was determined that the well was a dual completion with isolated screened intervals in the Phosphoria and Wells Formations. Therefore, the well was retained for monitoring groundwater elevation, and in particular, is useful for evaluating the vertical gradient between the two formations. It was not, however, retained for water quality monitoring in the Wells Formation due to uncertainty associated with its construction. MMW020 is used for water quality monitoring in this location.

2.1.3 Deviations from Work Plan

Deviations from the MWITM work plan resulted from hydrogeological conditions encountered at the drilling sites and from comments and direction received from the agencies. Written agency comments were documented in *Agency/Tribal Direction for Groundwater Characterization and Data Gap Analysis at P4 Production, LLC Enoch Valley, Henry and Ballard Mine Sties, Idaho*

(GW Technical Direction Document) (May 2007). Additional agency direction was received in meetings held June 18 and 19, 2007.

2.1.3.1 Addition of Henry Mine Wells

In response to the *GW Technical Direction Document*, two monitoring wells, MMW022 and MMW023, were drilled at Henry Mine in addition to the original scope of the MWITM. MMW022 is screened in the Dinwoody Formation and MMW023 is screened in the Wells Formation. Information pertaining to these wells may be found in subsequent sections of this report.

2.1.3.2 Completion of Alluvial Locations as Dinwoody Wells

At some drilling locations groundwater was not observed in the alluvium and as a result, drilling was continued into the Dinwoody Formation. Wells where this occurred are: MMW007, MMW008, MMW012, and MMW013 (Enoch Valley Mine) and MMW018 (Ballard Mine). Details pertaining to these wells are included in subsequent sections of this report. <u>It is possible that low-yielding groundwater zones were present that were not identified using the rotary drilling method. This possibility will be further evaluated in 2008 during an investigation using direct-push coring and sampling.</u>

2.1.3.3 Relocation of MMW009 and MMW018

MMW009 was proposed for completion within existing well MPW020 at Enoch Valley Mine. During field activity it was discovered that MPW020 was originally drilled to 810 feet below ground surface (bgs), with casing advanced to 461 feet bgs and backfilled with cuttings and bentonite to approximately 700 feet bgs. Therefore, the well does not extend into the Wells Formation. Given anticipated drilling challenges and additional costs, the advantage of reconstructing MPW020 as monitoring well MMW009 was lost. An alternative location for MMW009 was selected in the northwest portion of Enoch Valley Mine on waste rock dump MWD091. This deviation was documented in a memorandum to the agencies titled *Enoch Valley Production Well Conversion to Monitoring Well MMW009* (MWH, August 2007).

The location of MMW018 was originally cited along a stream channel within the mine boundary, near the eastern edge of Ballard Mine waste rock dump MWD082. In response to the *GW Technical Direction Document*, land owner permission was granted to install the well further down stream near stream sampling station MST095.

2.1.3.4 Modification of Borehole Drilling and Well Construction

Borehole drilling and well construction specification changes are documented in a memorandum to the agencies titled *Screen and Filter Pack Field Change for Phase II Well Installation* (MWH, August 2007).

Fine sediments, encountered while drilling, caused loss of drill cutting circulation and swelling or collapse of boreholes. In response, temporary steel casing was advanced to the total depth of the borings. Wells were constructed inside the steel casing as it was pulled from the bore hole.

The well construction specifications outlined in the MWITM, called for 0.020 slotted well screen and 10/20 grade sand filter pack. Due to silty conditions, particularly in the alluvium and Wells Formation, a change to finer 0.010 slotted screen and 20/40 sand was made.

2.2 GEOLOGIC AND HYDROGEOLOGIC DATA

A discussion of well drilling and installation activities for each new well is given in the following subsections. Table 2-1 summarizes well drilling, construction, location, and elevation of the new monitoring wells. Table 2-2 summarizes details of existing wells. Individual drilling logs and well construction diagrams are provided in Appendix A.

Groundwater was denoted in the field by airlifted water, penetration rate, and changes in lithology. Hydrogeologic testing (e.g., slug tests) will be conducted during the Phase IIb investigation in 2008.

2.2.1 Alluvial and Basalt Systems

2.2.1.1 Enoch Valley Mine Area

MMW007: This well is located near the toe of Enoch Valley Mine (EVM) South Waste Rock Dump MWD091 and near EVM South Dump Seep, MDS026 (Drawing 5). The well was originally drilled August 14, 2007; however, well installation could not be completed due to bridging sand. Consequently, the PVC casing was pulled and the sand pack was drilled out of the boring August 21, 2007 and the well re-installed August 23, 2007. The boring was initially drilled open-hole to 80 feet bgs. To avoid caving problems, temporary 8-inch diameter steel casing with an Atlas drive shoe was advanced the total depth. Formation samples (circulated drilling cuttings) were collected and logged at 5-foot intervals. First groundwater was encountered at 88 feet bgs in the Dinwoody Formation, near the contact with alluvial material. Airlifted groundwater flow rate was 0.5 to 1 gpm at final drilling depth of 90 feet bgs. The well was screened using 0.010 slotted, schedule 40 PVC screen from 70 to 90 feet bgs.

MMW008: This well is located approximately 300 feet southeast of well MMW007 (Drawing 5). The boring was drilled open hole on August 21, 2007. Formation samples (circulated drilling cuttings) were collected and logged at 5-foot intervals from surface to total depth of 198 feet bgs. The formation samples consisted of alluvial clay, sand, and gravel from the surface to the Dinwoody contact at 130 feet bgs. At 160 feet bgs, the drilling was stopped for 20 minutes after which, 3 gallons of water were purged from the hole. Water production quickly ceased, so drilling was continued. A fracture was encountered at 175 feet bgs and the drill cuttings appeared more angular. At 180 feet bgs, drilling stopped while the support truck was re-filled with water. When drilling commenced, one hour later, only two gallons of water were purged from the boring. At 195 to 199 feet bgs water production increased to 8 gallons per minute (gpm).

Swelling clays made it necessary to case the boring to allow well installation to proceed. Temporary 8-inch steel casing with a Rotex drill shoe was advanced to total depth on August 23,

2007. Once the casing was advanced to the total drilled depth of 204 feet bgs, the drill shoe was cut from the end of the casing and buried in the drill hole with 16/30 sand from 197 to 204 feet bgs. The well was constructed using 0.010 slotted, schedule 80 PVC screen from 177 to 197 feet bgs. Well installation was completed August 25, 2007.

MMW012: This well is located near the western edge of the EVM North Waste Rock Dump MWD092 (Drawing 5). The boring was originally drilled August 13, 2007; however, well installation could not be completed due to swelling clays. Consequently, the PVC casing was pulled and the boring was re-drilled and cased with 10-inch temporary steel casing to 63 feet bgs on August 24, 2007. Formation samples were collected and logged at 5-foot intervals from surface to 63 feet bgs. A productive groundwater zone was not encountered while drilling. This is most likely because the boring was drilled in late summer and the area is known to be wet only in spring. Because previously drilled shallow wells produced water in the upper Dinwoody Formation, drilling was continued past the alluvium - Dinwoody Formation contact. The contact was determined to be at 37 to 40 feet bgs. Well installation was completed August 28, 2007. The well was constructed using 0.010 slotted, schedule 40 PVC screen from 28 to 58 feet bgs. It is anticipated the well will contain water during the spring and early summer months.

MMW013: This well is located in the alluvial flow field of Rasmussen Creek near the center of EVM South Waste Rock Dump MWD091 and downgradient of dump seep MDS025 (Drawing 5). The boring was drilled August 11, 2007. Temporary 10-inch steel casing was installed to 17 feet bgs and the boring was drilled open hole to 35 feet bgs. Formation samples were collected and logged at 5-foot intervals from surface to total depth. The contact between the alluvium - Dinwoody Formation was at 6 feet bgs. First groundwater was encountered at 29 feet bgs. Airlifted groundwater flow rate was 1 gpm at final drilling depth of 36 feet bgs. Well installation was completed August 13, 2007 using 0.010 slotted, schedule 40 PVC screen from 25 to 35 feet bgs.

2.2.1.2 Henry Mine Area

MMW010: This well was installed downgradient of Henry Mine Center Pit Waste Rock Dump MWD086 on the northwestern side of stock pond MSP014 (Drawing 5). The boring was drilled August 29, 2007. Temporary 8-inch steel casing was installed to the total depth drilled of 38 feet bgs. Formation samples were collected and logged at 5-foot intervals. Samples consisted of loamy soil and fine sandy clay. First groundwater was encountered at 17 feet bgs and the groundwater flow rate was 1/2gpm at final depth. Well installation was completed September 9, 2007 using 0.010 slotted, schedule 40 PVC screen, in the alluvium, from 12 to 32 feet bgs.

MMW014: This well is located near the northeastern edge of Henry Mine Southern Waste Rock Dump MWD090 and downgradient of dump seep MDS022 (Drawing 5). The boring was drilled August 11, 2007 and temporary 10-inch steel casing was installed to the total drilled depth of 22 feet bgs. Formation samples, collected and logged at 5-foot intervals, consisted of sandy clay and clay. First groundwater was encountered at 9 feet bgs. Well installation was completed August 11, 2007 using 0.010 slotted, schedule 80 PVC screen from 7 to 22 feet bgs.

MMW019: This well was installed along the edge of Center Henry Pit MMP043 near the Little Blackfoot River (Drawing 5). The boring was drilled August 10, 2007, open hole, to a total depth of 14 feet bgs. Formation samples, collected and logged at 5-foot intervals, consisted of clay to 6 feet and black mudstone to total depth. First groundwater was encountered at 10 feet bgs. Well installation was completed August 10, 2007 using 0.020 slotted, schedule 40 PVC screen from 4 to 14 feet bgs.

2.2.1.3 Ballard Mine Area

MMW017: This well is located west of Ballard Mine Overburden Dump MWD080 and downstream of Dredge Pond MSP010 (Drawing 6). The boring was originally drilled on July 26, 2007. Temporary 10-inch steel casing was used to case the boring to 17 feet bgs and drilling was continued open hole to 115 feet bgs. Formation samples, collected and logged at 5-foot intervals, consisted of very fine sandy clay to total depth. First groundwater was not determined during initial drilling so the borehole was allowed to stand open. The next day, the boring had swelled causing the hole to close up to 31 feet bgs and was dry. On August 24, 2007 the total depth of the boring was 25 feet bgs and was dry. Drilling was continued by adding additional, temporary 10-inch casing. Drilling continued using as little water as possible to circulate cuttings. First water was encountered at 35 feet bgs. Drilling was stopped at 62 feet bgs, where the airlifted groundwater flow rate was 2.5 gpm. Prior to installing the well, a firm base was constructed at the bottom of the boring using 3/8" bentonite pellets from 60 to 62 feet bgs and 20/40 sand from 50 to 56 feet bgs. Well installation was completed August 27, 2007 using 0.010 slotted, schedule 40 PVC screen from 36 to 56 feet bgs.

MMW018: This well is located near headwater stream station MST095 and downgradient of Ballard Mine overburden dump MWD082 (Drawing 6). The boring was drilled August 12, 2007, open hole, to a total depth of 33 feet bgs. Formation samples, collected and logged at 5-foot intervals, consisted of fine sandy clay to 30 feet and Dinwoody Formation from 30 to 33 feet bgs. First groundwater was encountered at 31 feet bgs. Well installation was completed August 12, 2007 using 0.010 slotted, schedule 80 PVC screen from 18 to 33 feet bgs.

2.2.2 Dinwoody Formation

2.2.2.1 Ballard Mine Area

Well MMW018, was installed in the upper, weathered zone of the Dinwoody Formation. Because the weathered Dinwoody Formation appears to be in hydrologic connection with the alluvial system, this well is considered to monitor the shallow system. Further hydrogeologic conceptualization and investigation recommendations for the Dinwoody Formation at Ballard Mine are presented in subsequent sections of this report.

2.2.2.2 Henry Mine Area

MMW022: This well is located on the northeast lobe of Henry Mine waste rock dump MWD086 (Drawing 5). The boring was originally drilled on July 14 and 15, 2007. Temporary 10-inch steel casing was used to case the boring to 18 feet bgs and drilling was continued open hole to 360 feet bgs. Formation samples, collected and logged at 5-foot intervals, consisted of waste rock to 5 feet bgs and Dinwoody Formation to total depth. First groundwater was encountered at 320 feet bgs. During the drillers shift break the boring swelled in to 300 feet bgs. On July 25, 2007 the boring was cleaned out to 365 feet bgs and the following morning, July 26th, the boring had swelled to 320 feet bgs. The boring was re-drilled to 380 feet bgs using foam to stabilize the hole. Well installation commenced immediately following removal of the drill rod on July 26th. During installation, it was discovered that the boring had once again swelled to 326 feet bgs. Because the objective was to screen the well in the area of first water (320 feet bgs), well installation proceeded. The installation was completed July 28, 2007 using 0.020 slotted, schedule 80 PVC screen from 306 to 326 feet bgs.

2.2.2.3 Enoch Valley Mine Area

Wells MMW007 and MMW008 were installed in the upper, weathered zone of the Dinwoody Formation. Because the weathered Dinwoody Formation appears to be in hydrologic connection with the alluvial system, these wells are considered to monitor the shallow system. Further hydrogeologic conceptualization and investigation recommendations for the Dinwoody Formation at Enoch Valley Mine are presented in subsequent sections of this report.

2.2.3 Wells Formation

2.2.3.1 Ballard Mine Area

MMW006: This well is located on the south side of West Ballard Mine Pit MMP035. The boring was drilled July 21 and 22, 2007 (Drawing 6). Temporary 10-inch steel casing was installed to 17 feet bgs and the boring continued open hole, to a total depth of 335 feet bgs. The well was located on a Wells Formation outcrop. Drilling samples, collected and logged at 5-foot intervals, consisted of fine grain sandstone interbedded with limestone. First groundwater was encountered at 315 feet bgs at 12 gpm. Drilling was stopped at 335 feet bgs, where the airlifted groundwater flow rate was 15 gpm. During installation it was discovered that the boring had caved in to 332 feet bgs, so a sump was placed below the screen from 330 to 332 feet bgs. Well installation was completed July 23, 2007 using 0.020 slotted, schedule 80 PVC screen from 330-310 feet bgs.

MMW020: This well is on the east side of West Ballard Mine Pit MMP035 (Drawing 6). This well acts as a replacement of MMW001 as discussed in the previous technical memorandum (MWH 2007a). The well was originally sited on the waste rock dump approximately 100 feet northeast of MMW001. This first boring, referred to as MMW020-A, was drilled September 22, 2007 to 120 feet bgs open hole. Due to a boulder, temporary 8-inch casing could be advanced only to 60 feet bgs open hole. Several attempts to drill out the boulder failed and the boring was abandoned using bentonite chips. Two other attempts were made to drill approximately 15 and 30 feet from the original boring; however, boulders were again encountered. Therefore, it was decided to move the location off of the waste rock dump. The new location selected is located approximately 40 feet south of MMW001. The borehole log for this location is referred to as MMW020-B; however the well identification number is simply MMW020.

Boring MMW020-B was drilled September 23 – 27, 2007. The boring was drilled as a 10-inch, open hole to 220 feet bgs. Temporary 8-inch steel casing with a Rotex drill shoe was then installed in the 10-inch boring. This allowed for considerable reduction in friction loss as the casing was advanced to total depth. Drilling samples, collected and logged at 5-foot intervals, consisted of chert to 145 feet bgs, Phosphoria Formation from approximately 145 to 370 feet bgs, and Wells Formation, fine grain sandstone from 370 to 416 feet bgs. First groundwater was encountered at 225 feet bgs at 10 gpm with the rate increasing to 30 gpm at 250 feet. The rate decreased to 5 gpm at 315 feet bgs and increased to 15 gpm upon entry into the Wells Formation at 370 feet bgs. Once the casing was advanced to the total depth of 416 feet bgs, the drill shoe was cut from the end of the casing and buried in the drill hole prior to well installation using bentonite pellets from 413 to 416 feet bgs and 20/40 sand from 408 to 413 feet bgs. The well was constructed using 0.010 slotted, schedule 80 PVC screen from 388 to 408 feet bgs. Well installation was completed October 5, 2007.

MMW021: This well is on the west side of West Ballard Mine Pit MMP035 (Drawing 6). This well acts as a replacement of MMW002, which was decommissioned August 9, 2007. The well was originally sited approximately 80 feet south of MMW002. This first boring, referred to as MMW021-A, was drilled July 11 and 12, 2007. Temporary 10-inch casing was installed to 37 feet bgs and the borehole continued open hole to a total depth of 320 feet bgs. Drilling samples, collected and logged at 5-foot intervals, consisted of waste rock to 25 feet bgs and Wells Formation, fine grain sandstone and interbedded limestone from 25 to 320 feet bgs. First groundwater in MMW021-A was encountered at 285 feet bgs at 10 gpm and increased to 15 gpm at total depth. Due to very fine, loosely cemented sands in the Wells Formation, the borehole caved in. It was re-drilled July 24 and 25 to 300 feet bgs but caved in again to 265 feet bgs. On August 26, 2007 an attempt was made to re-drill the boring using temporary 8-inch casing with a Rotex drill shoe. The attempt failed because the casing wedged in the existing borehole. An attempt was then made, the following day, to bail sediments from the borehole but this too failed as the bailer hung up in the boring. It was decided that a new boring would have to be drilled in order to install casing. MMW021-A boring was abandoned August 30, 2007 using bentonite chips.

The location selected for boring MMW021 is approximately 50 feet south of MMW002. The borehole log for this location is referred to as MMW021-B; however the well identification number is simply, MMW021. Boring MMW021-B, was drilled September 10, 11, and 14, 2007. The boring was drilled using temporary 8-inch steel casing with a Rotex drill shoe to the total depth of 260 feet bgs. Drilling samples, collected and logged at 5-foot intervals, consisted of waste rock to 25 feet bgs and Wells Formation, fine grain sandstone and interbedded limestone from 25 to 260 feet bgs. First groundwater was encountered at 238 feet bgs at 13 gpm with the rate decreasing to 3 gpm at 260 feet bgs. The decreased flow rate is most likely due to the sealing off of water from above by the casing. Once the casing was advanced to the total depth of 260 feet bgs, the drill shoe was cut from the end of the casing and buried in the drill hole prior to well installation using bentonite pellets from 255 to 260 feet bgs and 20/40 sand from 250 to 255 feet bgs. The well was constructed using 0.010 slotted, schedule 80 PVC screen from 230 to 250 feet bgs. Well installation was completed September 24, 2007.

2.2.3.2 Henry Mine Area

MMW011: This well is northwest of the Center Henry Pit MMP042, immediately south of the Little Blackfoot River (Drawing 5). The well was originally sited on Wells Formation approximately 400 feet west of MMW003. Due to site access constraints, the boring was first drilled approximately 50 feet northwest of MMW003; this boring is referred to as MMW011-A. MMW011-A, was drilled July 28, 2007. Temporary 10-inch casing was installed to 17 feet bgs and the borehole continued open hole to a total depth of 200 feet bgs. Drilling samples, collected and logged at 5-foot intervals, consisted of Phosphoria Formation total depth. First groundwater in MMW011-A was encountered at 95 feet bgs at 9 gpm and increased to 15 gpm at 110 feet bgs. Drilling was stopped because drill water and cutting runoff was nearing the Little Blackfoot River. A pit needed to be installed but because of the proximity of the boring to the river a pit of adequate depth could not be dug. Also, the depth of the Wells Formation was anticipated to be approximately 350 to 400 feet bgs, nearly doubling the estimated total depth of the well. A decision was made to abandon MMW011-A and build a road and containment system at the originally proposed location. MMW011-A was abandoned July 31, 2007 using bentonite slurry.

The location selected for boring MMW011 is approximately 400 feet west of MMW003 on the edge of a Wells Formation ridge. The borehole log for this location is referred to as MMW011-B; however the well identification number is simply, MMW011. Boring MMW011-B was drilled to 30 feet bgs on July 31, 2007. Temporary 10-inch steel casing was installed to 17 feet bgs. The drill rig broke down July 31. Drilling commenced August 7, 2007 and was drilled open hole to 180 feet bgs. Drilling samples were fine grained, Wells Formation sandstone. No water was observed so the borehole was left overnight. No water was present the next morning. The driller attempted to continue drilling but lost circulation. It was determined that the boring would need to be cased. Equipment was procured such that casing could be advanced as the boring was drilled. Additional drill cutting containment features were also built around the boring. Drilling commenced once again on August 27, 2007. At that time, the borehole had caved in to 100 feet bgs. Temporary 8-inch casing was advanced to 120 feet bgs. Drilling samples, collected and logged at 5-foot intervals, consisted of fine grained, Wells Formation sandstone to 120 feet bgs. First groundwater was encountered at 101 feet bgs at 10 gpm with the rate increasing to 60 gpm at 120 feet bgs. Because the original boring had been drilled to 180 feet bgs, 5 feet of 20/40 sand was placed in the bottom of the boring to provide a firm base for the well. The well was constructed using 0.010 slotted, schedule 80 PVC screen from 95 to 115 feet bgs. Well installation was completed September 8, 2007.

MMW023: This well is located in the Henry Mine North Pit MMP041 (Drawing 5). The boring was drilled August 29, 30 and September 6-9, 2007. Temporary 8-inch steel casing with a Rotex drill shoe was installed to 300 feet bgs. The boring was continued open hole to 360 feet bgs. At that point drilling circulation ceased due to fine sands in the Wells Formation. The hole was backfilled up to the casing allowing the drill bit to fire and casing advancement to proceed. Casing was advanced to 362 feet bgs but circulation ceased again and drilling was stopped.

Drilling samples, collected and logged at 5-foot intervals, consisted of Phosphoria Formation to 350 feet bgs and Wells Formation fine grained sandstone from 350 to 362 feet bgs. First groundwater was encountered at 128 feet bgs at 60 gpm with the rate increasing to 65 gpm at 188 feet bgs. At total depth the flow rate was estimated to be 100 gpm. Once the casing was advanced to the total depth of 362 feet bgs, the drill shoe was cut from the end of the casing and buried in the drill hole prior to well installation using bentonite pellets from 361 to 362 feet bgs and 20/40 sand from 357 to 361 feet bgs. The well was constructed using 0.010 slotted, schedule 80 PVC screen from 352 to 357 feet bgs. Well installation was completed September 11, 2007.

2.2.3.3 Enoch Valley Mine Area

MMW009: This well is located near the center of Enoch Valley Mine North Dump MWD091 (Drawing 5). The boring was drilled September 29, 30, and October 8, 9, 10, and 12, 2007. Temporary 8-inch steel casing with a Rotex drill shoe was installed to 360 feet, at which point, the drill shoe broke free of the casing. The drill bit remained locked into the drill shoe so drilling continued, without casing, to 570 feet bgs. At that point drilling circulation ceased, due to fine sands in the Wells Formation, and drilling was stopped.

Drilling samples, collected and logged at 5-foot intervals, consisted of waste rock from 0 to 90 feet bgs, Phosphoria Formation from 90 to 530 feet bgs, and Wells Formation fine grained sandstone from 530 to 570 feet bgs. First groundwater was encountered at 150 feet bgs and at total depth the flow rate was estimated to be 200 gpm. Once the boring was advanced to the total depth of 570 feet bgs, the drill shoe was released from the drill bit and buried in the drill hole prior to well installation using bentonite pellets from 559 to 563 feet bgs and 20/40 sand from 554 to 559 feet bgs. The well was constructed using 0.010 slotted, schedule 80 PVC screen from 549 to 554 feet bgs. Well installation was completed October 26, 2007.

Table 2-1
2007 New Wells Drilling and Construction Detail

Mine	Well ID	Well Location	Installation Date	Boring TD (ft bgs)	Well Completion TD (ft bgs)	Depth Water Encountered when Drilling (ft bgs)	Fall 2007 Static Water Level (ft bgs)	Fall 2007 Total Se (mg/L)	Depth to Formation Contacts (ft bgs)	Formation At Screen	Elevation of MP[a] (ft AMSL)	Screened Interval (ft bgs)	Screen Length (ft)
Enoch Valley Mine	MMW007	South of EVM South Dump; near edge of dump footprint	8/23/2007	90	89.5	88	40.7	0.002	0-Alluvium	Alluvium (sandy clay) and Dinwoody	6614.7	90-70	20
	MMW008	South of EVM South Dump; south and downgradient of MMW007	8/25/2007	204	197	160, 175	24.5	<0.0010	0-Alluvium 130-Dinwoody	Alluvium (silty clay, sand and gravel) and Dinwoody	6599.7	197-177	20
	MMW009	Central North Dump (MWD091)	10/26/2007	563	554	150 (Wells Fm contact 530)	209	0.0010	0-Waste Rock 90-Phosphoria 530-Wells	Wells	6721.6	554-549	5
	MMW012	Northwest of EVM North Dump in Lone Pine Creek alluvial flow field	8/28/2007	58	58	Dinwoody contact @ 60 ft-BGL	Dry	Dry	0-Alluvium 37-Dinwoody	Alluvium (sandy clay) and Dinwoody	6399.7	58-28	30
	MMW013	Southwest of EVM in Rasmussen Creek alluvial flow field	8/13/2007	35	35	29	12.6	<0.0010	0-Alluvium 6-Dinwoody	Dinwoody	6619.9	35-25	10
Henry Mine	MMW010	Southeast of Center Henry Pit; near MPW023	9/9/2007	38	32	17	21.9	<0.0010	0-Alluvium	Alluvium (clay)	6439.9	32-12	20
	MMW011	Northwest of Center Henry Pit; south of Little Blackfoot River	9/8/2007	120	115	101	89.6	<0.0010	0-Wells	Wells	6251.1	115-95	20
	MMW014	Southeast of Henry Mine center pit in Lone Pine Creek alluvial flow field	8/11/2007	22	22	9	2.9	<0.0010	0-Alluvium	Alluvium (silty clay)	6429.0	22-7	15
	MMW019	North of Henry Mine center pit	8/10/2007	14	14	10	13.3	<0.0010	0-Phosphoria	Phosphoria	6240.0	14-4	10
	MMW022	Northeast lobe of Henry Mine waste rock dump MWD086	7/28/2007	360	326	320, 340	204.6	0.016	0-Waste Rock 5-Dinwoody	Dinwoody	6623.6	326-306	20
	MMW023	Henry Mine North Pit (MMP041)	9/11/2007	362	357	128, 188	105.94	0.003	0-Phosphoria 350-Wells	Wells	6455.5	357-352	5
Ballard Mine	MMW006	South of West Ballard Pit; south of waste rock dumps	7/23/2007	335	330	315-335	263.7	0.080	0-Wells	Wells	6499.6	330-310	20
	MMW017	Northwest of Ballard Mine into Long Valley Creek alluvial flow field	8/27/2007	62	57	35	32.8	0.13	0-Alluvium	Alluvium (very fine sandy clay)	6315.2	56-36	20
	MMW018	East of Ballard Mine in Wooley Valley alluvial flow field	8/12/2007	33	33	31	11.9	0.029	0-Alluvium 30-Dinwoody	Alluvium (sandy clay, fine gravel) and Dinwoody	6459.3	33-18	15
	MMW020	East side of West Ballard Pit (MMP035); replacement of MMW001	10/5/2007	416	408	225, 250, 315, 370	284.3	0.017	0-Rex Chert 370-Wells	Wells	6536.8	408-388	20
	MMW021	West side of West Ballard Pit (MMP035); replacement of MMW002	9/24/2007	260	250	229, 238	208.9	0.047	0-Waste Rock 25-Wells	Wells	6444.5	250-230	20

Table 2-1 Continued 2007 New Wells Drilling and Construction Detail														
Mine	Well ID	Screen Slot Size (in)	Sand Size at Screen	Casing Type	Primary Filter Interval (ft bgs)	Secondary Filter Interval (ft bgs)	Bentonite Seal (3/8" Pellet) Interval (ft bgs)	Bentonite Seal (Slurry) Interval (ft bgs)	Sump (ft bgs)	Drill Shoe Burial (ft bgs)	Backfill (ft bgs)	Permanent Steel Casing Depth (ft bgs)	Pump Depth (ft bgs)	Pump Intake Depth (if drop tube used) (ft bgs)
Enoch Valley Mine	MMW007	0.010	16x30	Schedule 40 PVC	90-64	NA	64-61	61-surface	NA	NA	NA	NA	87	NA
	MMW008	0.010	16x30	Schedule 80 PVC	197-170	NA	170-160	160-surface	NA	16x30 sand 204-197	NA	NA	197	NA
	MMW009	0.010	20x40	Schedule 80 PVC	554-546	NA	546-536	536-surface	NA	Pellets 563-559; 20x40 sand 559-554	NA	360	NA	NA
	MMW012	0.010	20x40	Schedule 40 PVC	58-23	NA	23-13	13-surface	NA	NA	NA	NA	55	NA
	MMW013	0.020	10x20	Schedule 40 PVC	35-21	NA	21-16	16-surface	NA	NA	NA	NA	31	NA
Henry Mine	MMW010	0.010	20x40	Schedule 40 PVC	32-8	NA	NA	8-surface	NA	NA	20x40 sand 38-32	NA	29	NA
	MMW011	0.010	20x40	Schedule 80 PVC	115-85	NA	85-75	75-surface	NA	NA	20x40 sand 120-115	NA	112	NA
	MMW014	0.010	20x40	Schedule 80 PVC	22-4	NA	4-surface	NA	NA	NA	NA	NA	18	NA
	MMW019	0.020	10x20	Schedule 40 PVC	14-3	NA	3.0-1	NA	NA	NA	NA	NA	12	NA
	MMW022	0.020	10x20	Schedule 80 PVC	326-286	20x40 sand 286-281	281-271	271-surface	NA	NA	Boring caved 360-326	NA	223	323
	MMW023	0.010	20x40	Schedule 80 PVC	357-350	NA	350-340	340-surface	NA	Pellets 362-361; 20x40 sand 361-357	NA	NA	132	352
Ballard Mine	MMW006	0.020	10x20	Schedule 80 PVC	335-305	20x40 sand 305-300	300-290	290-0	332-330	NA	NA	NA	327	NA
	MMW017	0.010	20x40	Schedule 40 PVC	56-31	NA	31-20	20-surface	NA	NA	Pellets 62-60; 20x40 sand 60-56	NA	56	NA
	MMW018	0.010	20x40	Schedule 80 PVC	33-15	NA	15-10	10-surface	NA	NA	NA	NA	30	NA
	MMW020	1.010	20x40	Schedule 80 PVC	408-378	NA	378-368	368-surface	NA	Pellets 416-413; 20x40 sand 413-408	NA	NA	320	403
	MMW021	1.010	20x40	Schedule 80 PVC	250-219	NA	219-210	210-surface	NA	Pellets 260-255; 20x40 sand 255-250	NA	NA	242	NA

Table 2-2 Existing Monitoring Wells										
Mine or Well Type	**Well ID**	**Well Location / Name**	**Completion Date**	**Total Depth (fbtoc)**	**Casing Depth (fbls)**	**Depth Water Encountered while drilling (fbls)**	**Perforation Intervals (fbls, log description)**	**Formation**	**Water Level Spring, Fall (fbtoc)**	**Total Se[g]- Ave/Range (mg/L)**
Enoch Valley Mine	MPW006N (A)	Southeast corner of EVM South Dump (MWD092) (Agrium Production wells)	1993	650	650	420-460, 520-560	280-380, gravel; 520-580, sand/sandstone	Phosphoria and Wells	267[b]	0.00035
	MPW006S (B)	Southeast corner of EVM South Dump (MWD092)(Agrium Production wells)	1992	390	390	45-48, 80-100, 350-390	80-90, gravel; 350-385, black shale/interbedded limestone	Alluvium and Phosphoria	32[b]	0.00035
	MPW019	EVM shop/office	1990	255	235	189-255	175-235, clay/hard rock/broken rock	ND	137[b]	0.00059 / 0.00035-0.00082
	MPW020	Southwest, down structural dip, from eastern ridge of EVM pit MMP045	1990	700 (drilled to 810, backfill to 700))	461	440-510, 720-726 (constructed to 700)	401-461, cherty shales/phosphate	Phosphoria	260[b]	0.00035
Henry Mine	MMW003 (Abandoned)	South of Henry Mine north pit (MMP043)	ND	140	34	No log	No screen	ND	8.27, 51.2	0.032[d]
	MMW004	North of Henry Mine north pit (MMP043)	ND	77	55	No log	No screen	ND	35.41, 45.21	0.00050
	MPW022	South Henry Pit dewatering well	1980	165	Steel to 151	122-125	No screen	ND	72.23, 76.34	0.00050
	MPW023	Center Henry Pit dewatering well	ND	312	160	No log	No screen	ND	32.72, 40.8	0.00050[d]
Ballard Mine	MMW001	East side of West Ballard pit (MMP035)	1992	450	Steel to 271[c]; PVC to 450	170-190, 212-265	Steel casing perforation 191-271 ,phosphate; PVC screen 420-450, hard limestone	Phosphoria and Wells	268.87, 287.8	0.069
	MMW002 (Abandoned)	West side of West Ballard pit (MMP035)	1992	350	Steel to 20; PVC to 348	270-282, 286-330	288-308 med. Limestone; 328-348 hard limestone	Wells	221.53, 223.8	0.022
	MW-15A	West Ballard Mine near MST068	2006	46.5	PVC to TD	ND	31.5-41.5	Alluvium	22.83, 20.71	1.11/0.81-1.99
	MW-16A	Southwest Ballard Mine near MST069	2006	36.8	PVC to TD	ND	21.8-31.8	Alluvium	10.10, 6.71	0.071/0.049-0.11
Agricultural Wells	MAW001[f]	School Bus Well	ND	ND	ND	No log	ND	ND	ND	0.00050
	MAW002	(b) (6) Field Well	1969	154	153	142-153	14-146, clay, coarse sand	Alluvium[e]	17.6[b]	0.00050
	MAW003	(b) (6) Field Well	1987	180	180	25-40, 150-155	20-30 gravel, clay, 160-180 hard rock	Thaynes[f]	10[b]	0.00050
	MAW004[f]	(b) (6) Field Well	ND	ND	ND	No log	ND	ND	ND	0.00050
	MAW005	(b) (6) Field Well	1990	280	239	220-235, 245-260, 271-280	159-199 clay, 199-239 hard, broken limestone	Alluvium, Wells[e]	220[b]	0.00050
	MAW006	(b) (6) Field Well West	1988	120	109	27-33, 63-69, 87-102	89-109, hard lava	Basalt[e]	27[b]	0.00050
	MAW007	Field Well North	1988	120	119	53-57, 93-120	59-119 sand stone, clay	Alluvium[e]	60[b]	0.00050
Domestic Wells	MDW001	(b) (6) ouse Well	1988	160	160	142-150, 150-160	70-110 clay , gravel; 139-160 hard lava, hard, broken limestone	Travertine[e]	13[b]	0.00050
	MDW002	House Well	1987	180	159	25-40, 150-155	20-30 clay, grave1; 160-180 hard rock	Alluvium, Thaynes[e]	10[b]	0.00050
	MDW003[f]	(b) (6) ouse Well	ND	ND	ND	No log	ND	ND	ND	0.0020
	MDW004[f]	House Well	ND	ND	ND	No log	ND	ND	ND	0.00050
	MDW005	Cedar Bay RV Park Well	1969	46	46	8-14, 28-46	40-45, white loose rock	Alluvium, Travertine[e]	6[b]	0.00050
	MDW006[f]	(b) House Well	ND	ND	ND	No log	ND	ND	ND	0.00050

Notes:
a. Wells MPW006 (A) and MPW006 (B) are pumped into one line and are not sampled individually.
b. Static water level (fbls) noted on well log.
c. MMW001 steel casing is perforated from 191-271 fbls within Phosphoria Formation. The perforated steel area is in contact with gravel pack from 191' to 210' and bentonite seal from 210' to 271'.
d. Filtered Se result reported. Unfiltered Se data is not available for the sampling station.
e. Formation was interpreted from logs and geologic maps, so some wells may be open to multiple formations.
f. Well logs were not found for these agricultural and domestic wells, so construction information is limited.
g. As reported in MWH (2007a).
ND - Not Determined. fbls - feet below land surface. fbtoc - feet below top of casing

2.3 WATER QUALITY DATA

2.3.1 Summary of Water Quality Sampling Activities and Analytical Procedures

Groundwater sampling was conducted in Spring 2006 and Fall 2007. Samples were collected from monitoring and production wells, seeps, springs, headwater streams, and ponds.

2.3.2 Quality Control and Quality Assurance

Samples from wells were collected consistent with USEPA protocols detailed in Appendix H of the Monitoring Well Installation Technical Memorandum (MWH, 2007a). Samples from springs, seeps, headwater streams, and ponds were collected as grab samples using sample containers appropriate for the intended analyses. Once collected, all samples were labeled and stored at 4 degrees C. All samples were kept under chain of custody through shipment.

Quality control samples were collected throughout each sampling event in accordance with the sampling and handling protocol detailed in the 2004 SI Work Plan – Program Quality Assurance Plan (MWH, 2004). Quality control samples, including duplicates, equipment blanks, and sample blanks represent a minimum of 10% of all monitoring samples collected during each sampling event.

2.3.3 Sample Analyses

Samples were analyzed for the analytes presented Table 2-3. Samples were shipped to the primary laboratory, ACZ Laboratories, Inc., in Steamboat Springs, CO. ACZ analyzed samples for all analytes except speciated selenium (selenate and selenite) and gross alpha and beta; these were analyzed by Applied Speciation and Consulting, LLC and GEL Laboratories, LLC respectively. University of Idaho Laboratory performed analyses on the quality control samples.

Table 2-3
Groundwater Monitoring Analyses

Parameter	Method	EDL	Reporting Units	Holding Time (days)
alkalinity, total	SM2320B	2	mg/L	14
aluminum	M200.7 ICP	0.03	mg/L	180
antimony*	M200.8 ICP/MS	0.0004	mg/L	180
arsenic*	M200.8 ICP/MS	0.0001	mg/L	180
barium*	M200.7 ICP	0.0001	mg/L	180
beryllium*	M200.7 ICP	0.0001	mg/L	180
boron*	M200.7 ICP	0.025	mg/L	180
cadmium	M200.8 ICP/MS	0.0001	mg/L	180
calcium	M200.7 ICP	0.2	mg/L	180
chloride	M300.0	0.5	mg/L	28
chromium*	M200.8 ICP/MS	0.0001	mg/L	180
cobalt*	M200.7 ICP	0.01	mg/L	180
copper*	M200.7 ICP	0.01	mg/L	180
fluoride*	M300.0	0.5	mg/L	28
gross alpha*	M900.0	2	pCi/L	180
gross beta*	M900.0	4	pCi/L	180
hardness	Calculation	1.5	mg/L	-
iron	M200.7 ICP	0.01	mg/L	180
ferrous iron, dissolved (Field)	HACH	0.01	mg/L	-
ferric iron, dissolved	Calculation	0.01	mg/L	-
lead*	M200.8 ICP/MS	0.04	mg/L	180
manganese	M200.8 ICP/MS	0.0005	mg/L	180
magnesium*	M200.7 ICP	0.2	mg/L	180
mercury*	M245.1	0.0002	mg/L	28
molybdenum*	M200.7 ICP	0.01	mg/L	180
nickel	M200.8 ICP/MS	0.0006	mg/L	180
nitrogen (as nitrate and nitrite)	M 353.2	0.02	mg/L	28
orthophosphate	M 365.1	0.005	mg/L	28
pH	M150.1	0.1	pH	-
potassium	M200.7 ICP	0.3	mg/L	180
selenium	SM3114 B, AA-Hydride	0.001	mg/L	180
selenite	IC-ICP/MS	0.01	μg/L	1
selenate	IC-ICP/MS	0.01	μg/L	1
silver*	M200.7 ICP	0.01	mg/L	180
sodium	M200.7 ICP	0.3	mg/L	180
sulfate	M300.0	0.5	mg/L	28
thallium*	M200.8 ICP/MS	0.0001	mg/L	180
total dissolved solids*	M160.1	10	mg/L	7
total suspended solids*	M160.2	10	mg/L	7
uranium*	M200.8 ICP/MS	0.0001	mg/L	180
vanadium	M200.8 ICP/MS	0.0002	mg/L	180
zinc	M200.8 ICP/MS	0.002	mg/L	180

* Analytes included as a screening for one groundwater sampling event.
Methods are for media (non-blank) samples.
Equipment and field blanks will be analyzed for unfiltered results. For regulatory compliance, all media samples will be analyzed for unfiltered metals.
EDL – Estimated Detection Limit; the laboratory analytical limit does not reflect possible sample-specific elevation of the reporting limit due to dilution, contamination or other issues identified during the data validation process.

2.3.4 Water Quality Results

Results of all analyses are presented in Appendices B, C, and D. Tables 2-4, 2-5, and 2-6 present total selenium results from samples collected in 2006 and 2007 from wells and surface expressed groundwater stations.

2.3.4.1 Data Validation

Data validation is conducted on the data received from the laboratories to review and evaluate the procedures and methods used by the laboratories. Data validation evaluates the quality and quantity of the data received and provides qualification of data that are outside of prescribed limitations. Validation of data presented in this report has not been finalized.

2.3.4.2 Ballard Mine Area

Groundwater flow paths associated with all sampled stations, at Ballard Mine, are discussed in more detail in Section 3.2.

Samples collected from monitoring wells MMW001, MMW006, MW-15A, MW-16A, and MMW017 indicate levels of total selenium above the 0.05 mg/L standard. All other wells were below the groundwater standard. MMW001 (0.11 mg/L in spring 2006) and MMW006 (0.080 mg/L in fall 2007) are screened in the Wells Formation. Well MMW001 had a total selenium value of 0.11 mg/L in spring 2006; however this dropped to 0.028 mg/L in fall 2007. MMW017 (0.013 mg/L in fall 2007), MW-15A (0.52 mg/L in fall 2006; 0.81 mg/L and 1.99 mg/L in spring and fall 2007), and MW-16A (0.054 mg/L in fall 2006; 0.11 mg/L and 0.049 mg/L in spring and fall 2007) are screened in the alluvium to the west and south sides of Ballard Mine.

Samples from the following stations indicated elevated levels of total selenium: dump seeps MDS030 and MDS033; springs MSG004 and MSG006; headwater streams MST095 and MST096; and ponds MSP010, MSP012, and MSP013.

2.3.4.3 Henry Mine Area

All wells sampled at Henry Mine had total selenium concentrations below the groundwater standard of 0.05 mg/L. Ponds MSP014, MSP015, MSP016, and MSP055 indicate elevated total selenium above the groundwater standard. Groundwater flow paths associated with all sampled stations are discussed in more detail in Section 3.3.

2.3.4.4 Enoch Valley Mine Area

All wells sampled at Enoch Valley Mine had total selenium concentrations below the groundwater standard of 0.05 mg/L. Dump seeps MDS025, MDS026 and ponds MSP017, MSP018, and MSP019 indicate total selenium levels above the groundwater standard. Groundwater flow paths associated with all sampled stations are discussed in more detail in Section 3.4.

2.3.5 Aquifer Solids Analyses

Aquifer material samples were collected from drill cuttings during drilling of new borings. Samples were selected from the depth intervals where water was first encountered, at contacts between different formations, and at the bottom of the boring. The purpose was to obtain the concentrations of total metals and total organic carbon present in the aquifer solids. This information may be used when evaluating the geochemical aspects of the aquifer(s). Results of these analyses are presented in Appendix E.

2.3.6 Hydrochemical Typing

The major ion data from the groundwater sampling was used for preliminary water typing. This analysis is graphically displayed in Appendix G, and is discussed in Section 3.1.5.

Table 2-4
Monitoring and Production Wells - Unfiltered Selenium (mg/L)

Station			Selenium			
			2006*		2007*	
Mine	Name	ID	Spring	Flag	Fall	Flag
Enoch Valley Mine	South of EVM South Dump (MWD092); near edge of dump foot print	MMW007	NI		0.0020	
	South of EVM South Dump (MWD092); south and downgradient from MMW007	MMW008	NI		<0.0010	U
	Central North Dump (MWD091)	MMW009	NI		0.0010	
	Northwest of EVM North Dump (MWD091); in Lone Pine Creek Alluvial Flow Field	MMW012	NI		Dry	
	Southwest of EVM in Rasmussen Creek alluvial flow field	MMW013	NI		<0.0010	U
	Agrium Production Well	MPW006	NS		NS	
	EVM Shop Well	MPW019	<0.0010	UJ	<0.0010	U
	Degerstrom Well at EVM	MPW020	NS		NS	
Henry Mine	Henry North Pit Well S	MMW003	0.034	J	DC	
	Henry North Pit Well N	MMW004	NA		0.0020	
		MMW004-Avg	0.0013		NA	
		MMW004-R1	0.0010	J	NA	
		MMW004-R2	0.0020	J	NA	
		MMW004-R3	0.0010	J	NA	
	Southeast of Center Henry Pit (MMP042); near MPW 023	MMW010	NI		<0.0010	U
	NE of Center Henry Pit (MMP042); south Little Black Foot River	MMW011	NI		<0.0010	U
	Southeast of Henry Mine Center Pit (MMP042); in Lone Pine Creek alluvial flow field	MMW014	NI		<0.0010	U
	Southeast of Henry Mine Center Pit (MMP042)	MMW019	NI		<0.0010	U
	Northeast lobe of Henry Mine waste rock dump MWD086	MMW022	NI		NA	
		MMW022-Avg	NI		0.016	
		MMW022-R1	NI		0.017	
		MMW022-R2	NI		0.016	
		MMW022-R3	NI		0.016	
	Henry Mine north pit	MMW023	NI		0.0030	
	Henry South Pit Well	MPW022	<0.0010		<0.0010	U
	Henry Center Pit Well	MPW023	NS		<0.0010	U

Table 2-4 Continued Monitoring and Production Wells - Unfiltered Selenium (mg/L)						
Station			Selenium			
			2006*		2007*	
Mine	Name	ID	Spring	Flag	Fall	Flag
Ballard Mine	Ballard Pit East Well	MMW001	0.11	J	0.028	
		MMW001-Avg	NA		NA	
		MMW001-R1	NA		NA	
		MMW001-R2	NA		NA	
		MMW001-R3	NA		NA	
	Ballard Pit West Well	MMW002	0.0080	J	NS	
		MMW002-Avg	NA		NS	
		MMW002-R1	NA		NS	
		MMW002-R2	NA		NS	
		MMW002-R3	NA		NS	
	South of West Ballard Pit (MMP035)	MMW006	NI		NA	
		MMW006-Avg	NI		0.080	
		MMW006-R1	NI		0.080	J
		MMW006-R2	NI		0.080	
		MMW006-R3	NI		0.080	
	Northwest of Ballard Mine into Long Valley Creek alluvial flow field	MMW017	NI		0.13	
	East of Ballard Mine in Wooley Valley alluvial flow field	MMW018	NI		NA	
		MMW018-Avg	NI		0.029	
		MMW018-R1	NI		0.027	
		MMW018-R2	NI		0.030	
		MMW018-R3	NI		0.030	
	East side of West Ballard Pit (MMP035); replacement of MMW001	MMW020	NI		0.017	
	West side of West Ballard Pit (MMP035); replacement of MMW002	MMW021	NI		0.047	
	West Ballard Mine near MST068	MW-15A	0.81[a]		1.99	
	Southwest Ballard Mine near MST069	MW-16A	0.11[a]		0.049	

Notes:
*All data preliminary until finalization of data validation.
a. Data is from Spring 2007.
R1, R2, and R3 - Field replicates are shown as unaveraged as well as averaged where appropriate.
DC – Decommissioned. NA - Not Analyzed. NI - Not Installed. NS - Not Sampled.
Data qualifier definitions are:
(U) - The material was analyzed for, but was not detected above the level of the associated value. The associated value is the sample reporting limit. (J) - The result is an estimated quantity. (R) - The data are unusable. (UJ) - The material was analyzed for, but was not detected above the level of the associated value. The result is an estimate and may be inaccurate or imprecise.

Table 2-5 Seeps, Springs, and Headwater Streams - Unfiltered Selenium (mg/L)								
Station			Selenium					
			2006*		2007*			
Mine	Station Name	Station ID	Spring	Flag	Spring	Flag	Fall	Flag
Enoch Valley Mine	EVM W Dump Seep	MDS025	1.6		0.056		Dry	
	EVM S Dump Seep	MDS026	0.079		0.16		0.019	
	Hedin Spring	MSG001	0.0010	U	NA		0.0010	
		MSG001-Avg	NA		0.0020		NA	
		MSG001-R1	NA		0.0020		NA	
		MSG001-R2	NA		0.0020		NA	
		MSG001-R3	NA		0.0020		NA	
	W Rasmussen Creek #1, above Lone Pine Creek	MST059	Dry		NS		NS	
	W Rasmussen Creek #2, above Lone Pine Creek	MST060	Dry		NS		NS	
	W Rasmussen Creek #3, above Lone Pine Creek	MST061	Dry		NS		NS	
	Rasmussen Creek, Headwaters near EVM Pond	MST136	0.019		Dry		Dry	
	W Pond Creek Headwaters, below W Pond	MST144	0.15		Dry		Dry	
	E Fork Rasmussen Creek Headwaters	MST269	<0.0010	U	Dry		Dry	
	W Fork Rasmussen Creek Above Rasmussen Creek	MST274	0.0060		0.0030		0.0020	
		MST274-Avg	0.0067		NA		NA	
		MST274-R1	0.0070		NA		NA	
		MST274-R2	0.0070		NA		NA	
		MST274-R3	0.0060		NA		NA	
	N Fork Lone Pine Creek Above E Fork Lone Pine Creek	MST275	<0.0010	U	0.0010		NS	

Table 2-5 Continued Seeps, Springs, and Headwater Streams - Unfiltered Selenium (mg/L)								
Station			**Selenium**					
			2006*		**2007***			
Mine	**Station Name**	**Station ID**	**Spring**	**Flag**	**Spring**	**Flag**	**Fall**	**Flag**
Henry Mine	S Pit Overburden Dump Seep	MDS016	0.019		<0.0010	U	Dry	
	S Pit Overburden Limestone Drain	MDS022	0.0080		<0.0010	U	<0.0010	U
		MDS022-Avg	NA		NA		NA	
		MDS022-R1	NA		NA		NA	
		MDS022-R2	NA		NA		NA	
		MDS022-R3	NA		NA		NA	
	Taylor Spring	MSG002	0.0020		0.012		Dry	
	Lone Pine Creek Above W Fork Lone Pine Creek	MST058	0.011		NS		NS	
	W Fork Lone Pine Creek Above Tributary	MST064	0.020		NS		NS	
		MST064-Avg	NA		NS		NS	
		MST064-R1	NA		NS		NS	
		MST064-R2	NA		NS		NS	
		MST064-R3	NA		NS		NS	
	E Fork Lone Pine Creek Below Wooley Valley Mine	MST226	<0.0010		NS		NS	
	Tributary Above W Fork Lone Pine Creek	MST276	0.0050		0.0060		0.0030	
	Lone Pine Creek, Spring Fed Tributary	MST277	<0.0010		<0.0010	U	Dry	
		MST277-Avg	NA		NA		NA	
		MST277-R1	NA		NA		NA	
		MST277-R2	NA		NA		NA	
		MST277-R3	NA		NA		NA	

Table 2-5 Continued Seeps, Springs, and Headwater Streams - Unfiltered Selenium (mg/L)								
Station			Selenium					
			2006*		2007*			
Mine	Station Name	Station ID	Spring	Flag	Spring	Flag	Fall	Flag
Ballard Mine	Pit #2 Upper Dump Seep	MDS030	0.48		0.73		0.92	J
	Pit #2 Lower Dump Seep S	MDS031	0.49		0.77		NS	
	Pit #2 Lower Dump Seep N	MDS032	1.3		0.90		0.69	
	Goat Seep	MDS033	1.4		0.052		2.2	
	Garden Hose Spring	MSG003	0.46		0.57		0.53	
		MSG003-Avg	NA		NA		NA	
		MSG003-R1	NA		NA		NA	
		MSG003-R2	NA		NA		NA	
		MSG003-R3	NA		NA		NA	
	Holmgren Spring	MSG004	0.050		0.015		Dry	
		MSG004-Avg	NA		NA		NA	
		MSG004-R1	NA		NA		NA	
		MSG004-R2	NA		NA		NA	
		MSG004-R3	NA		NA		NA	
	Cattle Spring	MSG005	NA		0.0070		0.0020	
		MSG005-Avg	0.011		NA		NA	
		MSG005-R1	0.011		NA		NA	
		MSG005-R2	0.011		NA		NA	
		MSG005-R3	0.010		NA		NA	
	SE Spring	MSG006	0.16		0.26		0.018	
	Horse Spring	MSG007	0.012		0.0030		0.0030	
	Ballard Creek, Headwaters	MST067	0.58		0.022		Dry	
	W Fork Ballard Creek, Headwaters	MST068	0.89		Dry		Dry	
	Short Creek, Below BM	MST069	0.039		1.1		0.034	
		MST069-Avg	NA		NA		NA	
		MST069-R1	NA		NA		NA	
		MST069-R2	NA		NA		NA	
		MST069-R3	NA		NA		NA	
	N Fork Wooley Valley Creek (WVC), Above BM	MST093	<0.0010	U	<0.0010	U	Dry	
	Spring Fed Tributary #1 Above N Fork WVC Below BM	MST094	<0.0010	U	<0.0010	U	Dry	
	Spring Fed Tributary #2 Above N Fork WVC Below BM	MST095	0.35		0.073		Dry	
	Spring Fed Tributary #3 Above N Fork WVC Below BM	MST096	0.052		Dry		Dry	
	South Tributary to WVC	MST279	NS		<0.0010		<0.0010	

Notes:
*All data preliminary until finalization of data validation.
R1, R2, and R3 - Field replicates are shown as unaveraged as well as averaged where appropriate.
DC – Decommissioned. NA - Not Analyzed. NI - Not Installed. NS - Not Sampled.
Data qualifier definitions are:
(U) - The material was analyzed for, but was not detected above the level of the associated value. The associated value is the sample reporting limit. (J) - The result is an estimated quantity. (R) - The data are unusable. (UJ) - The material was analyzed for, but was not detected above the level of the associated value. The result is an estimate and may be inaccurate or imprecise.

Table 2-6 Ponds - Unfiltered Selenium (mg/L)								
Station			Selenium					
			2006*		2007*			
Mine	Name	ID	Spring	Flag	Spring	Flag	Fall	Flag
Enoch Valley Mine	EVM South Pond	MSP017	0.36		1.1		0.031	
		MSP017-Avg	NA		NA		NA	
		MSP017-R1	NA		NA		NA	
		MSP017-R2	NA		NA		NA	
		MSP017-R3	NA		NA		NA	
	EVM Keyhole Pond	MSP018	0.39		0.53		0.022	
	EVM Bat Cave Pond	MSP019	0.094		0.077		NA	
		MSP019-Avg	NA		NA		0.0090	
		MSP019-R1	NA		NA		0.0090	
		MSP019-R2	NA		NA		0.0090	
		MSP019-R3	NA		NA		0.0090	
	EVM West Pond	MSP020	0.082		0.045		0.040	
	EVM Stock Pond	MSP021	NA		NA		0.027	
		MSP021-Avg	0.015		0.23		NA	
		MSP021-R1	0.015		0.23		NA	
		MSP021-R2	0.015		0.23		NA	
		MSP021-R3	0.015		0.23		NA	
	EVM Tipple Pond	MSP022	0.020		0.035		0.025	
	EVM Haul Road Pond	MSP023	0.030		NS		NS	
	EVM Shop Pond	MSP031	<0.0010	U	0.0020		Dry	
Henry Mine	HM Henry Pond	MSP014	NA		NS		NS	
		MSP014-Avg	0.071		NS		NS	
		MSP014-R1	0.071		NS		NS	
		MSP014-R2	0.072		NS		NS	
		MSP014-R3	0.070		NS		NS	
	HM Smith Pond	MSP015	0.36		NS		NS	
		MSP015-Avg	NA		NS		NS	
		MSP015-R1	NA		NS		NS	
		MSP015-R2	NA		NS		NS	
		MSP015-R3	NA		NS		NS	
	HM Center Henry Pond	MSP016	0.38		NS		NS	
		MSP016-Avg	NA		NS		NS	
		MSP016-R1	NA		NS		NS	
		MSP016-R2	NA		NS		NS	
		MSP016-R3	NA		NS		NS	
	HM South Pit Pond	MSP055	0.35		0.36		Dry	

Table 2-6 Continued
Ponds - Unfiltered Selenium (mg/L)

Station			Selenium					
			2006*		2007*			
Mine	Name	ID	Spring	Flag	Spring	Flag	Fall	Flag
Ballard Mine	BM Dredge Pond	MSP010	0.98		NS		NS	
		MSP010-Avg	NA		NS		NS	
		MSP010-R1	NA		NS		NS	
		MSP010-R2	NA		NS		NS	
		MSP010-R3	NA		NS		NS	
	BM Upper Elk Pond	MSP011	0.042	R	0.043		Dry	
		MSP011-Avg	NA		NA		NS	
		MSP011-R1	NA		NA		NS	
		MSP011-R2	NA		NA		NS	
		MSP011-R3	NA		NA		NS	
	BM Lower Elk Pond	MSP012	0.076		0.15		NS	
	BM Northeast Pond	MSP013	0.19		NS		NS	
	BM MMP038 Stock Pond	MSP059	NS		0.027		NS	
	BM MMP036 Pond	MSP062	NS	U	Dry		Dry	

Notes:
*All data preliminary until finalization of data validation.
R1, R2, and R3 - Field replicates are shown as unaveraged as well as averaged where appropriate.
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3.0 UPDATED CONCEPTUAL MODELS

This section presents an updated discussion of the conceptual models for groundwater transport of selenium. Included in the discussion are the presentation of generic models for each source type and a discussion of the geochemical components that contribute to the release and transport of selenium. This is followed by the presentation and detailed discussion of specific completed groundwater pathways for each mine area. The final section presents a summary of the specific pathways including a tabular summary (the data gap matrix). Identification of key data gaps are also discussed in the section. Information regarding how P4/Monsanto plans to address these gaps is presented in Section 4.

In this discussion four types of flow systems relevant to the P4/Monsanto mines are considered:

- Shallow alluvial groundwater flow systems;
- Flow systems in the Dinwoody and Thaynes Formations;
- Flow systems in the Wells Formation; and
- Structurally controlled flow systems.

These systems can be related to three general types of flow systems identified for the Southwest Idaho Phosphate Region: (1) local; (2) intermediate; and (3) regional (Mohammad, 1976). These flow systems roughly correspond to the first three systems identified for the P4/Monsanto mines, with the structural systems most commonly being local and intermediate. However, exceptions commonly occur.

Generally, the shallow alluvial system is considered a local groundwater flow system. With local systems, the recharge areas are located adjacent to the discharge area (e.g., recharge on a hillside and the discharge to a stream in the adjacent valley floor). For this study, the uppermost weathered bedrock is included in the alluvial system because the hydrogeologic properties of the weathered bedrock are similar to the alluvium, and groundwater in the weathered bedrock appears to be in direct communication with the groundwater in the alluvium. The water table in this system may occur either in the alluvium or underlying weathered bedrock depending upon the season. Groundwater flow in colluvial deposits is also considered part of this system. Colluvial deposits are typically mixed deposits of soil and rock that results from the mass wasting of slopes. The unit Qw on the geologic maps included in this report includes colluvial ("hill wash") deposits. The alluvial system may be the most important system to evaluate. It is most likely to be impacted by seepage from the waste rock dumps (being the uppermost unit), and may provide the most direct link to potential receptors, whether it be through spring flow, discharge to nearby creeks, or potential plant uptake.

The Dinwoody and Thaynes Formations typically host either local or intermediate ground-water flow systems. The intermediate systems have the recharge area in one basin and the discharge area in the adjacent basin. There may be local systems that overlie intermediate groundwater flow systems. While the Dinwoody and Thaynes Formations commonly support local and intermediate flow systems, it is possible that more regional flow systems could be supported by these formations (recharge in one basin with discharge in basins that are not adjacent).

The Wells Formation is generally considered to host intermediate and/or regional ground-water flow systems. The recharge areas for a regional flow system may be separated from the discharge areas by several topographic highs and be overlain by both local and intermediate groundwater flow systems. It is, however, possible for the Wells Formation to also support local flow systems.

Structural flow systems resulting from faulting or more general fracturing may act as local or intermediate flow systems, but they may more commonly facilitate flow in the intermediate and regional flow systems to cross bedding. Faults may act as flow barriers or conduits, and in some cases may act as both. For example, thrust faults typically have a low permeability gouge zone; however, there may be significant fracturing adjacent to the actual fault that increases permeability along the thrust fault. Normal faults may have sufficient gouge to act as a flow barrier, or may be relatively open and act as a flow conduit and not be a barrier to flow. When conceptualizing the bedrock flow systems, the presence of structural features needs to considered.

Discharge characteristics can be used to help define the likely flow path and aid in classification of the associated groundwater flow system. The discharge from a local groundwater system (such as a spring or seep) generally varies considerably in flow (high discharge in the spring and early summer with minimal discharge by fall) has a low temperature and low total dissolved solids (reflecting a shallow flow path). Conversely, the discharge from a regional groundwater flow system typically has a more constant flow rate (because of a longer flow path) and can have a higher temperature (dependent on the depth of flow) and higher total dissolved solids.

3.1 GENERIC SOURCE MODELS

There are three primary settings where selenium-bearing shales could be exposed to the environment and have the potential to leach selenium to groundwater. These include:

- Locations where the waste shales have been placed in an external (outside the mine pit) waste dump;
- Locations where the waste shales have been used to backfill a mine pit; and
- Locations where the waste shales are exposed in an open mine pit wall.

The general conceptual models for each of these conditions are discussed in the following sections. There are some common components to the model that should be considered. These include:

- The P4 phosphate mines have been developed on mountainsides where the Phosphoria Formation is exposed at the surface. Typically, because of mining practices, the external waste rock is placed on the downhill side. This creates a condition where runoff and near surface groundwater flow is directed in one direction – downhill away from the mine. However, there are some exceptions:
- Within the Ballard Mine area there are locations where waste dumps are uphill of a mine pit due to repetition of the geologic section and the presence of multiple pits.
- At the Enoch Valley Mine the topography becomes relatively flat on the southern end of the mine.
- In addition, it should be noted that deeper flow could be independent of topography.

Discussion of monitoring well locations and results are presented in this section for illustration. Specifics on the monitoring wells and associated geology are presented in Section 2, and more detail is provided on how these results fit into specific pathways in Section 3.2.

Geochemistry necessarily plays a role in the conceptualization of the groundwater flow systems. Groundwater flow and a single source alone are not the prerequisite for groundwater contamination. The chemical processes must be present that allows the contaminant to dissolve and enter the groundwater system. Conversely, changes in the chemical environment may attenuate or self-remediate a contaminant plume. Therefore, a discussion of selenium geochemistry specific to the southeast Idaho phosphate mines follows the discussion of generic hydrogeological models in Section 3.1.4.

3.1.1 Waste Rock Dump

The general conceptual model for an external waste rock dump is presented in Drawing 7. In a 1976 study on the impacts of phosphate mining on groundwater systems, it was found that local flow systems associated with waste rock dumps are the primary pathway impacting groundwater quality (Mohammad, 1976). To support the conceptual model, some numerical modeling has been conducted using the USEPA HELP Model, Version 3 (Schroeder, et al., 1994). This modeling was largely conducted for illustrative purposes and is not specific to any one waste rock dump and uses generalized assumptions appropriate for the P4 mine areas. This modeling will be further refined with more detail presented in a future technical memorandum. This memorandum will also consider the results of the modeling efforts being conducted for the Blackfoot Bridge EIS, which also address waste rock dump infiltration and groundwater movement. Table 3-1 summarizes the input and output data. Each conceptual model component or group of related components is discussed below.

TABLE 3-1 INPUT AND OUTPUT VALUES FOR PRELIMINARY HELP MODEL SIMULATION OF A GENERIC P4 WASTE DUMP WATER BALANCE		
SIMULATION INPUTS		
Parameter Type	**For Flatter Slope Representative of Dump Top Surface**	**For Steeper Slope Representative of Dump Out Slope**
% area allowing runoff	50	95
layer number	1	1
layer type	Vertical Percolation	Vertical Percolation
layer depth (in)	18	18
soil texture number	8 (loam)	8 (loam)
porosity (vol/vol)	0.463	0.463
field capacity (vol/vol)	0.232	0.232
wilting point (vol/vol)	0.116	0.116
initial soil water content (vol/vol)	0.1976	0.1976
effective sat. hydr. cond.* (cm/sec)	3.7E-04	3.7E-04
layer number	2	2
layer type	Vertical Percolation	Vertical Percolation
layer depth (ft)	148.5	148.5
soil texture number	1 (poorly graded sand)	1 poorly graded sand)
porosity (vol/vol)	0.417	0.417
field capacity (vol/vol)	0.045	0.045
wilting point (vol/vol)	0.018	0.018
initial soil water content (vol/vol)	0.0471	0.0471
effective sat. hydr. cond. (cm/sec)	1E-02	1E-02
drainage length (ft)	218	218
drainage slope (%)	2	33
vegetative cover	Fair	Fair
SCS runoff curve number	79.6	81.1
fraction of area allowing runoff (%)	50	95
area projected on horizontal plane (acres)	1	1
evaporative zone depth (in)	16	16
initial water in evaporative zone (in)	3.093	3.056
upper limit of evaporative storage (in)	7.408	7.408
lower limit of evaporative storage (in)	1.856	1.856
initial snow water (in)	1.46	1.46
initial water in layer materials (in)	88.702	87.522
total initial water (in)	90.162	88.982
total subsurface inflow (in)	0	0
evapotranspiration date obtained from	Pocatello, ID	Pocatello, ID
station latitude (degrees)	42.55	42.55
maximum leaf area index	1.6	1.6
start of growing season (Julian date)	132	132
end of growing season (Julian date)	275	275
average annual wind speed (mph)	10.2	10.2
average first quarter relative humidity (%)	70	70
average second quarter relative humidity (%)	52	52

TABLE 3-1 INPUT AND OUTPUT VALUES FOR PRELIMINARY HELP MODEL SIMULATION OF A GENERIC P4 WASTE DUMP WATER BALANCE		
SIMULATION INPUTS		
Parameter Type	**For Flatter Slope Representative of Dump Top Surface**	**For Steeper Slope Representative of Dump Out Slope**
average third quarter relative humidity (%)	43	43
average fourth quarter relative humidity (%)	65	65
Precipitation data from	Somsen Ranch, ID	Somsen Ranch, ID
Air temperature data generated from coefficients for:	Pocatello, ID	Pocatello, ID
SIMULATION OUTPUTS		
precipitation (in.)**	23.64	23.64
runoff (in.)	2.359	5.152
evapotranspiration (in.)	14.423	14.393
percolation (in.)***	6.858	4.095

Notes:
* Multiplied by 2.49 for root channels in top half of evaporative zone
** Precipitation of P4 mine sites is estimated at 19 inches per year (MWH, 2007a) so daily data input for the HELP model is conservatively higher.
***Assumes steady-state and water that passes below the root zone will report ultimately as seepage from the bottom of the dump.

3.1.1.1 Precipitation and Evapotranspiration

The average annual precipitation in the vicinity of the P4 mines is approximately 19 inches, with approximately 50 percent coming as snowfall in the winter months (Somsen Ranch SNOTEL Station). (For the HELP modeling a daily record is needed and data from a nearby station was used with a 23.64 inch annual average.) A portion of the winter precipitation is lost to sublimation, but most of the remainder is stored as snow and becomes available for recharge and/or runoff during a relatively short spring snowmelt period.

Only minor amounts of precipitation infiltration occur during summer, fall and winter. The water is in the form of ice or snow in the winter. During the summer and much of the fall, evaporation and plant transpiration is effective in reducing infiltration to the waste rock. Evaporation occurs directly from the ground and plant surfaces, whereas transpiration occurs when the water enters the soil and is taken up by the plant then transpired back to the atmosphere. These two processes together are called evapotranspiration. The HELP model estimates that evapotranspiration represents approximately 60 percent of the water balance assuming a “fair” vegetation cover. Even without plants, evaporation of soil moisture may occur from capillary action (wicking of the water upward). However, if only evaporative losses are considered, the total amount of water removed from the system would obviously be less. In the spring, the plants are just coming back and the plant surface area is less, reducing the effectiveness of transpiration and, to some extent, evaporation.

The role of evapotranspiration for limiting infiltration is widely recognized and the use of “ET Covers” is a standard practice in mine closure world-wide. Often mine dumps are reclaimed with vegetation for purely aesthetic appeal and ecologic system restoration, but vegetation plays a very important role in reducing water infiltration into the waste material.

3.1.1.2 Runoff

Runoff is another important consideration when estimating infiltration through the waste rock. Runoff can typically range from 0 to as much as 90% of precipitation. Hydraulic properties of the soil, antecedent moisture conditions, vegetation, rainfall intensity and slope are all factors in the runoff component. For the example simulation, slopes of two to 33% were considered with the percentage of area allowing runoff ranging from 50 to 95%, for top surfaces and slopes, respectively. For the HELP model illustration runoff accounted for 10 to 20% of the water balance.

Runoff typically has a short contact time with the waste rock, and as such, will typically have lower concentrations of dissolved solutes (including selenium) as compared to water that infiltrates through the material and has a longer residence time. The surface material is also more likely to be completely leached of available contaminants. However, depending upon the amount of erosion that occurs with the runoff event, total concentrations may be elevated due to suspended solids. Stormwater controls are typically an important component of reclamation for this reason. Impacted runoff will typically be evaluated through surface water sampling, with impacts more likely to be seen during periods of high runoff (e.g., spring snowmelt).

Runoff can be included in a mine waste reclamation strategy for reducing infiltration by attempting to maximize runoff in a controlled manner to reduce erosion. This is typically done by developing consistent slope grades to avoid ponding, and either reducing focused flow or routing it to erosion resistant channels. Runoff routing is very important for helping to reduce infiltration during high intensity events like spring runoff.

3.1.1.3 Infiltration and Percolation

Once the precipitation infiltrates the soil and percolates beyond the root zone, it is no longer susceptible to evapotranspiration or runoff and will either percolate through the waste rock or be trapped in storage. The HELP model simulation suggest that infiltration could range from 15 to 30% of total precipitation. In the HELP modeling simulations presented in Table 3-1 the percolation below the root zone ranged from approximately 4.1 to 6.9 inches a year for various slopes based on 23.64 inches of precipitation per year. This compares to 3.5 inches/year (in/yr) reported for other HELP modeling for phosphate mine waste dumps in southeast Idaho (Tetra Tech, pending). The precipitation in the P4 mine areas is reported to be approximately 19 (in/yr). If the daily precipitation used in the HELP model were adjusted to the 19 (in/yr), it is likely that the data presented in Table 3-1 would be similar to the rate reported in other studies. This will be evaluated further in future studies.

For the purpose of this illustration, it is assumed that the water balance of the dump is at steady state with no net gain or loss of water to storage and annual average values are reported. Therefore, all water that infiltrates through the dump beyond the plant root zone flows through the dump and exits either as seepage or is transmitted through the bottom of the dump. In reality, hydrogeologic systems are often influenced by transient process. For example, often waste rock produced from a mine will have a low moisture content of typically less than 10%. This typically has to increase to 40% or higher before water will flow through the dump material.

During infiltration and percolation, the geochemical and biological processes are important. Flushing of soluble selenium from the rock surfaces is the primary early source of selenium impact. A secondary source of selenium can be from the oxidation of selenium-bearing sulfide minerals and organic matter, but the significance of this source is debatable. Attenuation processes may also act to retain some of the selenium within the waste rock environment. These geochemical processes are discussed further in Section 3.1.4 below.

Specific event infiltration has been measured for waste rock and native soils in the mine areas (Mohammad, 1976). Where the waste rock consisted of crushed shale and mudstone, the infiltration rates were measured at between 0.05 to 0.69 in/hr (six tests). Waste rock composed of chert, siltstone and mudstone exhibited infiltration rates of 1.35 to 1.95 in/hr (six tests). This is compared to native soils in the mine areas that ranged from 10 to 21 in/hr (five tests).

There has been considerable work done on this topic by various phosphate mining companies in southeast Idaho. As the investigation advances, these results will be incorporated into the overall investigation report, as appropriate.

3.1.1.4 Shallow Dump Discharge

Once water has passed through the waste rock it will either manifest as toe seepage or infiltrate to the underlying geology. Toe seepage usually occurs at the toe of the mine dump at the interface of the native ground surface and the base of the waste rock dump. This discharge often is expressed at depressions of the native topography such as stream channels. Key items that may influence the occurrence of lateral seepage are the hydraulic conductivity of the waste rock and underlying geology, in particular, the contrast between the two materials, and the topography of the contact. For example, if a highly permeable waste rock dump sits on steep topography with a low permeably underlying unit, toe seepage will be favored. If there is not a significant permeability contrast between the waste rock and underlying material, or if the underlying material is more permeable and the waste rock dumps are on a gentle slope, downward percolation may be favored.

As noted previously, the P4 waste rock dumps tend to be on hillsides with underlying pre-existing drainage channels. In addition, as noted in Section 2, the alluvial material was found to be dominated by silt and clay, suggesting lower permeability compared to the waste rock. This assumption will be tested in 2008. Typically, loose waste rock, particularly the bottom of dumps, tends to have relatively high permeability. The bottom of dumps tend to have higher permeability because when the rock is dumped the larger fragments tend to settle along the bottom of the slope and any compaction from equipment tends to occur on the upper surfaces. In the example shown on Drawing 7, a hydraulic conductivity of 10^{-3} cm/sec is assumed for the waste rock and 10^{-4} cm/sec for the underlying unit. In reality, the 10^{-3} cm/sec given in the example for the waste rock may be too low. The hydraulic conductivity values given by Mohammad (1976) for phosphate in waste rock in Southwest Idaho range between $6.5x10^{-2}$ and $2.7x10^{0}$ cm/sec. The fine sand to clay alluvium/colluvium could range from 10^{-3} to 10^{-6} cm/sec (for silts) (Freeze and Cherry, 1979). Given an order in magnitude or more difference in hydraulic conductivity between the units, a saturated zone along the bottom of the waste rock dump would be favored and this would result in lateral flow toward the toe of the waste rock dump.

Regardless of the precise hydraulic conductivities, the conditions at the P4 mines appear to be favorable for toe seeps based on the relatively low permeability foundation material (the clayey alluvial and colluvial material). This seepage may focus along narrow pre-existing stream channels that have been buried, or may manifest more diffusely and be difficult to identify.

Some portion of the water draining downward as unsaturated vertical flow will infiltrate the underlying geology and become groundwater. The geology that underlies the waste rock is typically colluvium, and in some cases alluvium or weathered bedrock. Generally, the weathered bedrock surface will be more permeable than the underlying unweathered bedrock, and near surface horizontal flow would be favored, similar to the colluvium and alluvium. Typically, flow in these units closely follows the overlying topography. At least in the vicinity of the mines, this horizon would not be used directly as a groundwater supply due to limited yield (low permeability and thickness). The most significant potential receptor is discharge to surface water, although plants may also uptake the shallow groundwater (in particular phreatophytes).

The alluvial systems observed at the P4 mines generally formed from fine-grained source rock, including the Dinwoody Formation. This has resulted in alluvium, colluvium and/or soil horizons that are fine-grained (clayey) and have relatively low permeabilities. In addition, the underlying source bedrock is of low permeability. Often the highest permeability zone is the uppermost surface of the underlying bedrock where the rock is disintegrating (weathering), but it has not broken completely down to clay and silt particles. This was observed in drilling during 2007 where the highest near-surface groundwater yields were near the contact with the Dinwoody Formation and the overlying clayey alluvial material. Hydraulic conductivity data to be collected in 2008 will help refine this conceptual model.

As presented in Section 2.2.9, 9 wells were installed in 2007 to monitor this pathway either in the alluvium/colluvium or the weathered bedrock horizon. In addition, numerous springs and dump seeps are monitored. At Enoch Valley and Henry Mines, the data generally suggest that most of the selenium is expressed shallowly in dump seeps and springs. Concentrations in the deeper alluvial and weathered bedrock wells are much less (see Section 2.3.4). At the Ballard Mine, impacts appear to be deeper within the alluvium.

3.1.1.5 Infiltration to Bedrock

Similar to the waste rock – alluvial case, the hydraulic conductivity contrasts between the bedrock and overlying unit will generally favor horizontal flow in the overlying unit. Significant exceptions can occur, however, where high-permeability units are present, most notably in the Wells Formation. In any case, some infiltration is expected to occur to underlying bedrock units barring the existence of upward hydraulic gradients. The actual amount of infiltration to the bedrock may be very small considering the processes discussed above. Given attenuation processes that will be enhanced in an anoxic environment, the actual flux of selenium may be very minor. Direct infiltration to a bedrock unit from a waste rock dump has been tested at one location at the Henry Mine. Monitoring well MMW022 was installed downgradient of an external waste dump in the deep Dinwoody Formation. While selenium was detected, it was well below the groundwater standard (0.016 mg/L vs. an MCL of 0.05 mg/L - see Section 2.3.4).

3.1.2 Backfilled Mine Pit

Drawing 8 presents a conceptual model for a generic backfilled mine pit. The components of precipitation, evapotranspiration, runoff, infiltration and percolation are generally the same as for the external waste rock dump discussed above. The primary difference is the discharge location, but the geochemical conditions may also be different with anoxic conditions being favored in the waste material.

Water that infiltrates the waste rock backfill will tend to percolate to the base of the backfill. There is the possibility that some water will infiltrate into the walls of the mine pit, but the majority should flow toward the pit bottom. The backfill in the pit bottom may be saturated either as a perched pore water zone or because the bottom of the pit is in contact with the local water table. If infiltration into the waste rock exceeds infiltration into the bedrock units, water will accumulate in the bottom of the pit.

Because of the geology and the mining practice, the bottom of the mine pit will be near or at the contact of the Meade Peak Member of the Phosphoria Formation with the top of the Wells Formation or possibly the Grandeur Tongue of the Park City Formation. The footwall unit is the Wells Formation with the remainder of the Phosphoria Formation and the Dinwoody Formation exposed in the opposite wall (the hanging wall). The Dinwoody Formation may or may not be exposed high up on the pit wall. The Meade Peak Member is generally recognized as a low permeability unit, therefore much of the leakage from the bottom of the mine pit may be into the uppermost Wells Formation. This pathway was specifically investigated through the installation of MMW009 at the northern end of the Enoch Valley Mine (see Section 2.2.3).

The backfilled mine pit is more ideal for creating anoxic conditions and promoting selenium attenuation. Unlike mine waste rock dumps, the opportunities for convective air flow through the waste rock in backfilled pits are greatly reduced because of the pit walls (i.e., only the top surface is exposed to the atmosphere). For a similar reason, the level of saturation is also higher, which also limits air ingress and encourages anaerobic bacteria growth. This greater tendency for anoxia will also limit any potential sulfide oxidation and secondary selenium release. With the introduction of anoxic water to the bedrock, attenuation may also be more efficient in the groundwater regime.

3.1.3 Open Mine Pit

Drawing 9 presents the general conceptual model of an open pit. While the opportunity for attenuation of selenium is less in this scenario because of oxidizing conditions, the amount of selenium that can be mobilized is greatly reduced because of limited exposure of selenium bearing shale. Water contact with the Meade Peak Member is limited to the pit walls and possibility some loose material in the pit bottom. This is in contrast to the much greater surface area exposed to leaching in a waste rock dump or pit backfill. The amount of surface area for selenium release is many orders of magnitude less. The amount of water available for infiltration to the Wells Formation is also limited by the low permeability of the Meade Peak Member in the base of the pit and evaporation. In rare cases, the water that runs into a pit may pond directly against the footwall Wells Formation. In this case, the mine pit will be a recharge area for the Wells Formation. Overall, the opportunity for impacting groundwater appears much less in a scenario with an open mine pit.

The open mine pit condition was tested through the installation of four wells in 2007. MMW023 was installed in the North Henry pit directly into the uppermost Wells Formation. Monitoring wells MMW006, MMW020 and MMW021 were installed around the West Ballard pit, although, several of these wells could also be impacted by waste rock sources. Similar to MMW023, MMW020 is installed in a location with the Wells Formation more likely to be impacted. MMW021 is installed in the footwall in a deeper position in the Wells Formation stratigraphy.

3.1.4 Conceptual Geochemical Model for Selenium Release and Groundwater Transport

The most general conceptual model for selenium release from the phosphate mining waste shales includes release from a mineral phase and transport through the waste rock dump via infiltration (Section 3.1.1). This is followed by either discharge to the surface as a seep, or infiltration and percolation to the groundwater system. There are however many geochemical processes, including those that increase and decrease the mobility of selenium, that may influence the concentrations of selenium as it migrates to a final receptor or discharge point.

When selenium-bearing waste rock is excavated and exposed to a new set of environmental conditions, there is the potential for selenium (and/or other elements) to be released from their in-situ mineral phases, become mobile and enter the aqueous environment. In order for this to occur there must be a source. Most rocks contain concentrations of many naturally occurring elements. The concentrations of some of these elements may be below the level of detection with common analytical methods, while others are the principal components of the rock. For those that become environmental issues, often the inorganic element(s) of concern has been enriched above normal background. With higher concentrations in the source rock there is an increased potential that any concentrations released to the environment will also be elevated, if the environmental and chemical conditions are favorable for mobilization.

The ultimate source of selenium is the geologic material produced as waste rock from the phosphate mining operations, specifically, black shale portions of the Meade Peak Member of the Phosphoria Formation. The Meade Peak Member is elevated in selenium. In one study, the mean selenium concentration for 31 defined lithologic units in the Meade Peak formation was 77 ppm (Desborough and Poole, 1983).

Later studies by the U.S. Geological Survey (USGS) focused specifically on the Meade Peak Member of the Phosphoria Formation where it has been exposed in the phosphate mines of Southeastern Idaho (see Herring and Grauch, 2004 for a summary). The Enoch Valley Mine was included in these detailed studies (Herring et al., 1999; Grauch et al., 2001; Herring et al., 2001). Selenium data collected from the Meade Peak Member at four mines, including Enoch Valley, indicated selenium concentrations up to 1,040 ppm with an average of 71 ppm. It was found that less weathered Meade Peak sections had higher selenium concentrations (Herring and Grauch, 2004). (The background concentration of selenium in shale is typically reported as less than 1 ppm (Connor and Shacklette, 1975). Therefore, a source with elevated concentrations of selenium is present. The USGS also conducted studies of elemental leaching from the same rock described in Herring and Grauch, 2004. Leachable selenium concentrations for two sections and one core at the Enoch Valley Mine were found to have geometric means of 0.005, 0.025 and 0.114 mg/L, respectively, with the most leachable selenium occurring in the least weathered core material (Herring, 2004).

The mineralogical form of the selenium plays a large role in the potential release to the environment. In relatively insoluble forms, the selenium may not be released into the environment as a contaminant, even if present in elevated concentrations, or released so slowly that it results in no measurable change in the environment. Some forms are readily released and others require secondary reactions for the selenium to be released. Selenium has chemical properties similar to sulfur and readily substitutes for sulfur in the lattices of sulfide minerals (Neal, 1990). Mineralogical studies by the U.S. Geological Survey (USGS) document the occurrence of seleniferous sphalerite, pyrite and organic compounds as well as native selenium in rocks of the Meade Peak Member. Selenium is also associated with organic matter (kerogen) in carbon rich rocks and with pyrite in rocks that have lower concentrations of organic carbon (Desborough et al., 1999). Selenium correlates most strongly with both organic carbon and total sulfur in the Meade Peak rocks (Herring and Grauch, 2004). Selenium bound in sulfides and organic carbon may be released as the result of oxidation reactions similar to the processes that form acid-rock drainage in metal and coal mine waste rock dumps.

It appears that the majority of the selenium in the Meade Peak waste rock is contained in sulfides and organic material that needs to be oxidized for the selenium to become mobile. However, geochemical studies of the Phosphoria Formation also indicate that a portion of the total selenium content occurs outside of these identified mineralogical reservoirs (Maxim, 2002), and studies suggest that there is a source of readily soluble selenium in relatively unweathered Meade Peak member rocks that can be released by short-term leaching (24 hour) even under anoxic conditions (Herring, 2004). This finding suggests that selenium may also be present as surficial complexes adsorbed onto clay, carbonate minerals, and oxides of iron, aluminum and manganese in the unweathered (unoxidized) rock. Such selenium may be released at a higher than background rate when the permeability of the rock mass is increased due to disturbances like mining. Oxyhydroxides along with organic matter constitute a secondary source of selenium in unweathered or minimal weathered Meade Peak rocks, with sulfide as the primary reservoir (Perkins and Foster, 2004). It is possible that this more readily soluble selenium is the result of in situ weathering of primary minerals and organic matter prior to mining.

It appears possible that the readily soluble forms of selenium, likely adsorbed selenite or selenate ions, are the most significant contributor to elevated aqueous selenium concentrations associated with the phosphate mining waste, and that the less soluble forms contribute less selenium in the near term following waste rock deposition. This in part may be due to sufficient neutralizing capacity in the waste rock, which inhibits the formation of the widespread acidic and biological conditions that enhance sulfide oxidation reactions and the subsequent release of selenium from sulfide minerals.

The conditions surrounding sulfide oxidation the development of acid rock drainage (ARD) are complex, but they are also very well studied (e.g., Alpers and Blowes, 1994). There are a number of ways a circum-neutral environment can slow sulfide oxidation. Most importantly, ARD generation is a process that occurs much more rapidly in the presence of catalyzing bacteria (e.g., *Thiobacillus ferrooxidans*), which only thrive in the low-pH environments. Another notable factor is that ferric iron (Fe^{3+}) will also oxidize sulfides, even in the absence of oxygen. In alkaline conditions the ferric iron will readily precipitate and form a secondary mineral, such as ferric hydroxide. However, under acidic conditions the ferric ion will remain in solution and be available to oxidize additional pyrite or other sulfide further advancing ARD formation. In addition, the secondary iron minerals that precipitate in the neutral environment may coat sulfide grains limiting oxygen and water availability for further oxidation (Nicholson, et al., 1990).

While the sulfide and carbon sites represent significant reservoirs for selenium, release from the sulfide and organic phases may be slow enough that measurable aqueous selenium may not occur. However, this may vary from site to site and may require further study to quantify.

It is the oxidizable sulfide and carbon fractions that can be most influenced by waste dump construction and reclamation activities because both oxygen and water infiltration are factors, as well as the other (carbonate) rock types that may be blended with the reactive rock and help neutralize potential acid generation. The water soluble portion is primarily affected by those measures that control water infiltration and percolation; although, local chemical environments within the waste rock dump can affect transport.

The selenium must be transported from the source to the surrounding environment once released from the mineral form. This requires both specific hydrochemical and hydrological processes. Reduced forms of selenium such as selenide (Se^{2-}) and native selenium (Se^0) are relatively insoluble in water, have low environmental mobility and potential for bio-availability (Seed et al., 2000; Neal, 1990). Exposure to atmospheric oxygen, however, can oxidize selenide (Se^{2-}) from sulfides and organic matter, and native selenium (Se^0) into more mobile forms such as selenite (SeO_3^{2-}) and selenate (SeO_4^{2-}).

Water movement must occur to transport the selenium away from the source. Water movement from the waste rock dump material into the groundwater environment is an important factor in describing the behavior of selenium in this area. However, water movement within the source waste rock is also important in affecting the rate and volume of selenium released to the surface water and groundwater systems. It has been commonly recognized that preferential flow through the waste rock is an important process and consideration when evaluating contaminant transport (e.g., Li, 2000, Molson et al., 2005). This has a couple of effects. The first is that selenium impacted seepage may appear sooner after a waste dump is constructed than if the whole dump has to reach field capacity before seepage occurs. This prediction is consistent with observations from the mine areas. Secondly, the ultimate volume of selenium loading may be dominated by water-rock contact along the preferential flow channels. Significant portions of the dump may never become saturated enough so that gravity drainage occurs. Therefore, only a fraction of the total mass of soluble selenium in the waste rock may be available for transport. This may be especially notable for the selenium mass that is contained within the matrix of rock fragments (i.e., the preferential flow path is around the rock fragment, not through it).

Once mobile and in transport, the potential exists for attenuation of selenium through the biologically mediated reduction of selenate to less mobile selenite and subsequent adsorption at any of the waste rock location settings and also along any of the three general types of groundwater flow systems. If mobile selenium forms are present, or if the top of a mine dump is oxygenated, selenium may be released and move in a mobile form. However, if the interior of the mine dump is oxygen deficient, it is possible for selenium to be reduced through biological processes and become less mobile and be retained in the dump environment through adsorption or precipitation. For this to be effective, a carbon source needs to be available for the bacterial growth and development of anoxic conditions. Such anoxic conditions are indicated by some dump seepages (Herring, 2004). In contrast, if a waste rock is well aerated, reduction of selenium is less likely and selenium transport through the dump is more likely. Factors that affect the air flow into a dump can include dump composition (i.e., material grain size), physical configuration, level of saturation, and placement and type of closure cover.

The sorption and oxidation/reduction processes that affect the transport of selenium have been studied. Selenium occurs as three principal species under oxidizing conditions and typical groundwater pH: selenite (SeO_3^{2-}), biselenite ($HSeO_3^-$) and selenate (SeO_4^{2-}) (Neal, 1990; Hem, 1989). Geochemical controls that reduce or limit the solubility of selenium in water include adsorption to mineral surfaces including iron, manganese and aluminum hydroxides and oxyhydroxides (Hayes et al. 1987; Balistrieri and Chao, 1990; and Rajan, 1979). Clay and carbonate minerals may also provide effective sorption surfaces for selenium (Bar-Yosef and Meek, 1987; Cowan et al., 1990). In general, selenate is much less strongly adsorbed to mineral surfaces than is selenite. Redox potential and pH both affect selenium solubility and sorption reactions with reducing conditions and lower pH favoring sorption (Neal, 1990; McLean and Bledsoe, 1992).

Redox reaction rates involving selenium are quite rapid (Pickering et al., 1995) with the aqueous species selenite (SeO_3^{2-}) and selenate (SeO_4^{2-}) being readily reduced to insoluble Se^0 (Hem, 1989). Likewise, native selenium (Se^0) and selenide (Se^{2-}) are easily oxidized to forms that are more mobile in the environment (Pickering et al., 1995). Microbial activity is an important process that affects the redox cycling of selenium in the environment. Selenate in solution is reduced to elemental selenium and precipitated by a number of anaerobic bacteria that are present in a wide range of sediment types (Stolz et al, 2002). Sulfate reducing bacteria are common at oxic-anoxic transition zones in soils and have the capacity to enzymatically reduce selenium in a number of ways (Hockin and Gadd, 2003). Selenate may be reduced to selenide by dissimilatory sulfate-reducing pathways (Zehr and Oremland, 1987). Assimilatory reduction of selenium occurs when sulfate-reducing bacteria incorporate selenide as a trace nutrient. Sulfate reducing bacteria are also able to reduce selenium oxyanions to elemental selenium by abiotic, but biologically mediated pathways (Hockin and Gadd, 2003). The remobilization of selenium through microbially mediated oxidation also occurs. However, the rates of oxidation are generally three to four orders of magnitude less than the reductive part of the cycle (Stolz et al, 2002). The microbial mediation of selenium to volatile methylated selenium species may be a factor in the persistence of selenium in soil and water (Neal, 1990).

If the selenium is released from the dump environment into the groundwater environment many of the same attenuation processes will continue to affect the selenium mobility. So long as an anoxic environment is present and some soluble organic matter is present natural selenium attenuation may occur.

In summary, the flushing of soluble selenium can occur throughout the waste rock dump. However, this may represent a limited long-term source of selenium because this reservoir is relatively small compared to the total selenium content. The sulfide oxidation process is likely to occur on the outer shell of the dump, but can progress inward with time. This may mobilize selenium and act as a longer-term source; however, sulfide oxidation processes appear relatively inhibited in the waste shales. While, soluble selenium may be mobilized throughout the dump, other processes may work to immobilize it. Pit backfills in particular are favorable for developing anoxic conditions because of more limited exterior dump surface area (a top surface) compared to exterior waste rock dumps with tops and sides. In these conditions, anaerobic bacteria many reduce the selenium to the less soluble selenite species, which may adsorb to a variety of mineral surfaces. Conversion to more reduced selenium species may result in direct precipitation. Organic matter is important for bacterial growth and the reduction process. The Phosphoria Formation, with its high organic content, may provide a carbon source and support the reduction process. A key consideration for this attenuation process is whether anoxic conditions develop in the waste rock dump. This is not a given because of processes such as thermal convection through the dump and level of water saturation. The presence or absence of anaerobic bacteria can be one explanation for the variation of selenium concentration in some dump seepage.

3.1.5 General Water Quality Typing

The major ion water quality data from 2007 were used to conduct a preliminary water typing analysis. This analysis is graphically displayed in Appendix G. Two end member water types are identified. These are Type 1, which is a calcium sulfate water type with higher dissolved solids, and Type 3, which is a calcium bicarbonate water type. The third type (Type 2) is intermediate between Type 1 and Type 3 and is characterized by a higher proportion of sodium and chloride.

It appears that the Type 1 water is generally associated with water that has contacted waste rock and the Type 3 water is representative of ambient water quality. However, this characterization is not absolute. Elevated selenium concentrations tend to be most commonly associated with the Type 1 water type, but also occur commonly in the Type 3 water. In addition, in rarer cases, Type 1 water is observed to not have elevated selenium concentrations.

The Type 2 water occurs in wells installed at the Henry Mine near the Little Blackfoot River. This water type is unique to this location. The source of the sodium-chloride component is uncertain, but the other unique feature in this area is the basalt flow (See Drawing 10).

The discussion presented here is brief and preliminary. A more detailed analysis and discussion will be presented with the data collected in 2008.

3.2 BALLARD MINE AREA

Of the three mine areas, the Ballard Mine is the most complex. Both the Henry and Enoch Valley Mines are developed along limbs of large-scale folds and therefore each mine tends to have a single, generally linear pit. The Ballard Mine geologic setting is more complex with folded stratigraphy displaced by several normal faults. Mining has occurred from a number of smaller pits. In effect, the central portion of the Ballard Mine is uplifted in a horst block with the stratigraphy stepping down to the east and west. This has resulted in the ore bed sequence being repeated four times within the mine area, with a central outcrop of the Wells Formation (see Drawings 10 and 11). The Phosphoria Formation is also relatively isolated from other outcrops of the Phosphoria Formation in this area. The east side of the mine area is bounded by the Slug Valley Fault, with the mine area on the downthrown side. This results in exposures of the Wells Formation to the east. The west side of the mine area is bounded by a large area of Quaternary sediments and basalt. Another range-bounding normal fault is postulated in this area by Mansfield (1927) with the stratigraphic sequence stepped and down-dropped to the west. There is no visible expression of this fault in the area of the Ballard Mine area.

The Ballard Mine is also unique for the P4 mine sites in that it straddles three watersheds. Surface water and shallow alluvial groundwater flow from the east side of the mine reports to a tributary of the Wooley Valley hydrologic system. On the west side water reports to either the upper reach of Long Valley Creek or a tributary of the Blackfoot River on the southwestern corner of the mine area.

In addition, the Ballard Mine is the oldest of the three mines having been mined between 1951 and 1969, and has been subjected to a lesser degree of reclamation. This lack of reclamation in some areas of the mine may be having an effect on the amount of selenium being released to the environment. A more detailed description of the Ballard Mine and history is provided in MWH (2007a).

3.2.1 Shallow Alluvial System

For this report, the shallow alluvial system includes alluvium, colluvium and uppermost weathered (decomposing) bedrock, because these units have similar hydrogeologic properties and form a single hydrogeologic system. However, the stratigraphy in the unit may be relatively complex with layers of differing hydraulic conductivities. This may result in the occurrence of semi-confined conditions when higher yield sediment layers are encountered. This same layering of sediment will also help inhibit the vertical migration of potential contaminants. The uppermost water table in this system may occur in the shallow alluvial system.

3.2.1.1 Alluvial Systems on East Side of Mine

The alluvial groundwater system on the east side of the Ballard Mine consists of a thin layer of older alluvium and colluvium (unit Qw) overlying the Triassic Dinwoody Formation (e.g., Section S, Drawing 15). Recent alluvial deposits (Qal) lie in the center of the adjacent valley along a tributary to Wooley Valley. It is postulated that groundwater flow in the alluvial system from the Ballard Mine, in this area, mirrors topography with water movement generally eastward toward the center of the valley then southward down valley. A portion of the groundwater in this flow system discharges from several springs. The presence of these springs may be due to local changes in the hydraulic transmissivity of the alluvial flow system forcing the water table to surface.

Sources of potential contaminants to the alluvial system on the east side of the Ballard Mine include external waste rock dumps MWD082 and MWD084 (Drawing 11). The generic model for an external waste dump, presented in Drawing 7, is a good representation of the source and transport pathways. Sections C, S and T (Drawings 12 and 15, respectively) provide specific conceptual illustrations of the flow system associated with the MWD082 and MWD084 waste dumps. Transport in the alluvium is expected to be relatively slow because of high silt and clay content in the sediment as indicated from the drilling of monitoring well MMW018. The most probable receptor would be through interaction and mixing with surface water, then through surface water exposure. It appears unlikely that the alluvium will yield sufficient water to provide a direct groundwater resource based on the limited drilling to date. Flow to the underlying bedrock units is also a possible component of the flow path.

In 2007, monitoring well MMW018 was located strategically in an alluvial flow system that should collect flow from a large portion of MWD082 and also in an area with elevated selenium in spring discharges. At this location, the first observed groundwater yield was at the alluvium/Dinwoody Formation contact at a depth of approximately 31 feet bgs with a static level of approximately 12 feet bgs. This suggests that confined or semi-confined conditions could exist in this groundwater zone. However, it is also possible that a water table condition exists but the overlaying sediments did not yield sufficient water to be identified as saturated during drilling (Table 2-1). The water level in MMW018 is similar to springs MSG006, MSG007 and MST096 suggesting hydrogeological relationship, and possibly an unconfined condition in the alluvial system associated with the valley fill sediments. There are four springs located above the MMW018 groundwater level in this area (MSG004, MSG005, MST094, and MST095). These springs occur near the topographic break from steeper hillside to shallower valley-bottom slopes. These springs may result due to the transition to flatter hydraulic gradients and/or the transition from colluvial material to the lower-energy sediments forming the flatter topography of the valley fill.

As presented in Section 2, the total selenium measured at MMW018 was 0.029 mg/L, and the springs in this area have total selenium concentrations ranging from 0.002 to 0.28 mg/L (MWH, 2007a). The two springs (MST095 and MSG006) in the same general flowpath as MMW018 have average total selenium concentrations between 0.01 and 0.35 mg/L. Compared to MMW018 (0.029 mg/L), the higher concentrations in the nearby springs indicates a vertical concentration gradient consistent with lateral contaminant transport from a surficial source area (waste rock pile MWD082).

The higher density of sampling points that will be afforded by the planned direct-push program in 2008 (MWH, 2007b) should be an effective method for helping to further characterize this system. Key questions regarding the hydrogeology of the alluvial system in that area and extent of contamination remain.

3.2.1.2 Alluvial Systems on West Side of Mine

The alluvial groundwater system on the west side of the Ballard Mine is comprised of the colluvium and older alluvium (Qw) shown on Drawing 11, and younger alluvium (Qal) along Long Valley Creek. The relationship of the alluvium to the pits and mine waste dumps of the Ballard Mine is illustrated on Section C (Drawing 12) and in more detail on Section R (Drawing 14). The configuration and flow system are very similar to the generic conceptual model described for an external waste dump in Section 3.1.1 and Drawing 7. Mohammad (1976) indicated this system to be an example of a local flow system.

Along the majority of the western flank of the Ballard Mine, the geologic and hydrogeologic configuration is similar and is well represented by Section R (Drawing 14). The alluvium, which near the mine may be colluvium, underlies the waste rock west of the West Ballard Mine Pit (MMP035) and appears to thicken westward toward the valley axis. Wells Formation is thought to underlie the alluvium and colluvium near the mine pit but how far it continues in the subsurface westward is uncertain.

In the area west of the Ballard Mine, alluvial groundwater was encountered in the two monitoring wells installed in 2006 (MW-15A and MW-16A) and one well installed in 2007 (MMW017). The static water level in these wells ranged from 8.3 to 32.8 feet bgs. In MMW017 water was first identified at approximately 35 feet. Given difficulties in identifying first water with the rotary drilling method, this probably indicated unconfined conditions in the alluvium. The alluvial materials at these locations were sandy clay and silt (see Section 2.2.1.3).

The potential source of selenium to the alluvial system is the waste rock on the downhill side of the mine pit similar to the generic section shown in Drawing 7 and on Section R (Drawing 14). With the possible exception of low-flow water well for stock watering, the most likely receptor for the alluvial system in this area would be surface water. The Ballard Mine sets approximately on the surface water divide for the valley to the west. The surface water that could potentially be impacted would be Long Valley Creek to the north and a short tributary to the Blackfoot River to the south. The water level in MMW017 in the fall of 2007 is below the drainages in the immediate area and would suggest such discharge would be to the north or south of the mine area in the alluvial valleys at lower elevations. Discharge could occur further up the drainages in the spring.

As discussed in Section 2.3.4, the alluvial groundwater to the west of the Ballard Mine has been investigated with the installation of three wells MMW017, MW-15A and MW-16A, all screened in alluvium. Total selenium concentrations in these monitoring wells measured in 2007 were 0.13, 1.99 and 0.049 mg/L, respectively. Springs MST069 and MST067 have also yielded sufficient water for sampling. These springs have produced samples with total selenium concentrations ranging from 0.022 to 1.1 mg/L. Similar to several springs on the east side of the mine, the elevation of the spring discharge is higher than the water levels measured in the wells. The analytical data indicate that the waste rock dumps are impacting the shallow alluvial groundwater system and that this area requires further characterization. The direct-push investigation planned for the spring of 2008 will provide the next step in the investigation.

3.2.2 Dinwoody and Thaynes System

The Dinwoody Formation is mapped to the east and south of the Ballard Mine area, as well as in the interior area between the various mine pits (Drawing 11). The Thaynes Formation (unit TRt) is not mapped in the vicinity of the mine. To the south, the Dinwoody Formation outcrops in the Fox Hills as a small peak several hundred feet higher than the mine area.

3.2.2.1 Dinwoody Formation on East Side of Mine

The Dinwoody Formation on the east side of the Ballard Mine area is generally not in direct contact with the mine waste rock dumps or the mine pits. Outcrops occur as elevated areas that were not mined or used for waste rock disposal (see Drawing 11). However, the Dinwoody

Formation underlies the alluvial and colluvial deposits throughout the area as illustrated on Sections S and T (Drawing 15).

Groundwater flow in the Dinwoody Formation in this area is expected to be from recharge near the mine to the east. The flow system, however, is relatively short as the Dinwoody Formation is offset by the inferred Slug Valley Fault just east of the mine as shown on Sections S and T. The Slug Valley Fault is a major northwest trending normal (extensional fault) that has been traced or inferred across the area of the P4 mines (see Drawing 10). The effect of the fault on the Dinwoody flow system is uncertain. If it acts as a flow barrier, it may result in a local flow system discharging to the alluvial system. However, if the fault is permeable, flow may be across the fault and contribute to an intermediate or regional flow system in the Wells Formation. Alternatively, the fault may direct flow southeastward toward Wooley Valley. Springs discharging from the Slug Valley Fault have not been mapped near the mine.

Prior to consideration of the effect of the Slug Valley Fault on the Dinwoody flow system, the potential for impact to the Dinwoody Formation needs to be conceptualized. There are at least two flow systems between the Dinwoody Formation and the mine wastes that may intercept much of the selenium impacted water. The first of these is the seepage flowpath that occurs at the base of the waste rock. The second is the alluvial flowpath including the more permeable upper "weathered" bedrock surface. Within the Dinwoody Formation, the deeper flow system is controlled by the bedding orientation and any secondary permeability developed from fracturing.

As described in Section 3.2.1.1 above, impacts in the shallowest alluvial zone is monitored through six springs. Monitoring well MMW018 was installed at the alluvium/Dinwoody contact with the water-bearing zone at approximately 31 feet bgs. The selenium concentration measured in the fall of 2007 in MMW018 was 0.029 mg/L, which was generally less than the nearby shallow springs. This vertical concentration gradient suggests that water in the deeper Dinwoody flow system would have even lower total selenium concentrations; however, this has not been confirmed.

Both the conceptualization of the area and the data to date suggest that selenium impacts may be confined to the shallower flow systems. However, this may need to be demonstrated through the collection of groundwater samples directly from the Dinwoody Formation in this area. Because selenium that reaches the Dinwoody Formation will need to pass through the shallower flow systems, the optimal location for a well in the Dinwoody Formation would be in the area of greatest impacts to the alluvial system. The selenium distribution will be better delineated after the direct-push groundwater sampling program is implemented in the spring of 2008. A location for the evaluation of groundwater in the Dinwoody flow system should be selected based on the results of the alluvial investigation.

3.2.2.2 Dinwoody Formation Located in Mine Interior

Four cross sections illustrate the configuration of the Dinwoody Formation flow system in the interior of the mine area. Sections H and R (Drawings 13 and 14) are sections oriented approximately perpendicular to the strike of the bedding. Section C on Drawing 12 is similar to Section H, but with a larger scale. Section Q on Drawing 14 is oriented approximately parallel to strike down the axis of the small syncline between the west and center mine pits.

Mohammad (1976) commented on this system in the interior of the mine area and suggested that it was one of the more significant flow systems at the Ballard Mine. He noted that the recharge area was in the middle pit and the discharge area was on the east wall of the west pit. There are at least four springs discharging near the top of the east wall of the west pit. Mohammad (1976) suggested that much of the flow system was contained in the fractured Rex Chert; however, given the position of these discharges, it appears that it may be also associated with the Dinwoody or the overlying waste rock dump more directly. Regardless, the key flow vector appears to be east to west discharging to the west pit. However, Section Q (Drawing 14) suggests that there may also be a minor component of flow toward the south.

Observations of the spring flow that discharges to the mine pit suggest that much of the flow down the dark Phosphoria Formation rocks to the mine pit evaporates along the pit walls or at the bottom of the pits. However, it is likely that selenium in this water may persist as a soluble salt, which during precipitation events is remobilized. Therefore, if the Wells Formation or other groundwater pathway is exposed in the bottom of the mine pit, this could result in an impact to groundwater flow system from a secondary source. These same conditions may exist in other Ballard pits but be less obvious. This could in part account for the impacts in monitoring wells MMW006, MMW020, MMW021 and needs to be considered when evaluating remedial options. If a southern flow component exists in the western mine interior it is expected that it will be local and will discharge to the alluvial system located along the southern boundary of the mine area. The area further south of the mine is a highland which is likely a recharge area for the Dinwoody Formation (see Drawing 11). Conceptually, flow from both the north and south in the Dinwoody Formation converge on the drainage. A fault is also postulated in this area that may focus the flow as shown on Section Q (Drawing 14). It is possible that spring MST069 on the southwestern corner of the mine area is associated with this flow system. This spring has had an average selenium concentration of 0.52 mg/L.

Monitoring well MW-16A is also located in the alluvium in this area. The concentration measured in this well in 2007 was lower at 0.049 mg/L. It is, however, more likely that the selenium concentrations in these locations are associated with a local alluvial system and the adjacent waste rock dumps. The alluvial area south of the mine is included in the direct-push alluvial investigation that will be conducted in the spring of 2008.

3.2.3 Deep Wells Formation System

The Wells Formation (ꟼPw) in the vicinity of the Ballard Mine has been identified as part of the regional flow system, with the ridge extending northward from the mine site identified as a recharge area for the regional system (Mohammad, 1976). Large surface exposures of Wells Formation, which represent recharge areas, are located to the west and north of the Ballard Mine area (Drawing 10). These areas represent locations of significant water influx into the regional flow system and by hydrogeologic principles will have higher hydraulic potential. Based on this supposition, the regional groundwater flow through the Ballard Mine area would likely be to the west with a possible southward component. However, the faulting and folding is likely to have a pronounced effect on the flow beneath the mine area. The general structural grain in the mine area is northwest-southeast. Faulting along the southern edge of the mine area and the north end of the Fox Hills may limit flow to the south and focus flow in the northwestward direction. In addition, effects of the faulting in the mine area may also compartmentalize the flow system in the mine area. <u>This compartmentalization likely restricts flow in the Wells Formation, although it is also possible that there may be some local faulting that enhances flow in specific locations and directions.</u> This is further described in a memorandum from Dr. Dale Ralston attached in Appendix F.

The position of the Ballard Mine and the associated Fox Hills is approximately located midway between the South and Henry West Lobe flow systems of Mayo (1982). It is unclear as to where water recharging to the regional flow system near the Ballard Mine will discharge. Specific discharge locations from the regional system have not been identified in the mine area (Mohammad, 1976). The nearest known discharge areas for the regional flow system are the springs near Henry or the Woodall Springs on the north end of the Aspen Range.

Hydrogeologic studies and modeling being conducted for the proposed Blackfoot Bridge Mine in the Aspen Range, 2.5 to 3 miles to the southwest of the Ballard Mine, suggest a northward flow component in the regional aquifer and that Woodall Springs is actually a high point in the regional system in the area. So the Woodall Springs are not a probable discharge area for the regional flow system in the Ballard Mine area. This suggests that the Henry Springs (elev. 6,150' AMSL) may be the discharge location for groundwater recharging to the Wells Formation in the Ballard Mine area. Water levels in the Wells Formation in the mine area range between approximately 6,235 and 6,255 feet AMSL.

The Henry Springs are located off the northwestern end of the Wooley Range which contains the Henry Mine. The springs are located in an area of travertine deposition that currently forms a peninsula in the Blackfoot Reservoir (Drawing 10 – springs are located just off the upper left corner of the map). The springs are located at the approximate intersection of the Henry Thrust Fault and the Slug Valley Fault, a normal fault. These structural features may have an influence on the location of the springs. The Ballard Mine area is located approximately 5.5 miles to the southeast of the spring along the structural grain and the inferred trace of the Slug Valley Fault.

The water discharging from these regional springs does travel a relatively long distance. The age of the water discharging from these springs is on the order of 10,000 to 20,000 years old (Mayo, 1982). <u>This suggests that potential impacts to the springs from the mine waste at the Ballard Mine are a remote possibility, at least in the near term.</u> The potential for impacts to other groundwater receptors will be dependent upon a number of other factors including travel time and distance from the source.

3.2.3.1 Wells Formation in Mine Interior Areas

There are surface exposures of the Wells Formation in the interior of the mine area. These exposures likely represent sources of direct groundwater recharge to the Wells Formation regional flow system. However, the position of these exposures in the core of the horst block in the Ballard Mine area result in the exposure at higher elevations, which because of mining practices, are less likely to be in contact with mine wastes. The relative position of the Wells Formation surface exposures with respect to the mine wastes are shown on Sections C (Drawing 12), Q (Drawing 14) and T (Drawing 15), and on the geologic map (Drawing 11).

As noted in the section above, the highland to the north of the Ballard Mine, which extends into the center of the mine, is thought to be a recharge area for the regional flow system (Mohammad, 1976). Given the large exposure of Wells Formation and the elevated topography north of the mine, there is potentially a component of flow from the north to the south and west. It appears less likely that there would be flow from the higher interior areas of the mine northward. Other factors to consider in this potential flowpath are the general lack of potential sources located directly on outcrops of Wells Formation in the higher interior areas. Further investigation of the Wells Formation in the higher interior areas of the mine appears unnecessary.

3.2.3.2 Wells Formation in West Pit Area

The potentiometric data for monitoring wells MMW006, MMW020 and MMW021 help illustrate the flow field in the Wells Formation in the west pit area. These well locations are shown on Drawing 11, and in cross section H and I (Drawing 13). What is suggested by these data is that flow is westward. The north-northwestward hydraulic gradient between MMW006 and MMW021 is almost flat (water levels of 6236.9 and 6235.6 ft-AMSL, respectively). The gradient between MMW020 (6,252.5 ft-AMSL) and MMW021 (6235.6 ft-AMSL) is approximately 17 feet of head difference over approximately 600 horizontal feet for a gradient of 0.028 southwestward. Given the presence of exposures of the Wells Formation to the east and northeast, a westward to southwestward groundwater flowpath away from the recharge area is reasonable. However, it needs to be noted that MMW020 and MMW021 are located in different hydrostratigraphic positions within the Wells Formation and the hydraulic head difference between the two wells represent a potential, but may not represent the actual predominate flow component. Instead it is likely that flow is in the direction of the strike of the bedding to the northwest. This concept is further developed by Dr. Ralston in the memorandum attached in Appendix F. However, as also discussed in the memorandum, the data also suggest that the groundwater flow in the Wells Formation in this area may be restricted because of the faulting.

Considering the Wells Formation monitoring wells individually, MMW006 exhibited the highest total selenium concentration of the three wells at 0.080 mg/L. One possible explanation for this is the abundance of waste rock near the location directly in contact with the Wells Formation near MMW006. Waste in this area exists primarily as an external waste rock dump, but there is also waste rock in the adjacent mine pit area.

The total selenium concentration measured at MMW020 was 0.017 mg/L, suggesting an impact, but below drinking water standards. The source of selenium may be originating in the area of the MMP036 mine pit (see Section H on Drawing 13). Water accumulating in the pit may infiltrate along one of the mapped faults to the Wells Formation then flow to the west toward the west mine pit (MMP035). Mohammad (1976) suggested that this was occurring, but that the infiltrating water was entering the Rex Chert and discharging in the west pit. An alternative potential source is a fault inferred beneath waste rock dump MWD093. A fault in this position may intercept some impacted flow in the Dinwoody or alluvial systems and allow it to migrate vertically to the Wells Formation.

As noted above, the potentiometric surface and the conceptual model suggest flow from MMW020 toward MMW021 (Section H). This may be over-simplified because this flow would cut across bedding, when the preferred pathway would be parallel to bedding. Alternatively, a local flow system may occur along bedding that would direct flow to the northwest, toward MMW017. Any bedrock groundwater flow toward MW-16A is likely deflected westward by an inferred fault (see Section Q, Drawing 14). Given this flow vector, the total selenium concentration of 0.047 mg/L in monitoring well MMW021 may originate from water percolating downward from waste rock overlying the Wells Formation along the west edge of the west pit (MMP035).

3.2.3.3 Wells Formation West of the Mine Area

The Wells Formation extends some distance west of the Ballard Mine area in the subsurface beneath the alluvial deposits. Mansfield (1927) postulated a range bounding normal fault beneath the alluvium west of the site that juxtaposed Phosphoria and Dinwoody Formations against the Wells Formation. The existence or position of this fault has apparently not been confirmed.

One potential pathway to the regional Wells Formation flow system is migration of impacted water from the alluvium in contact with waste rock into the Wells Formation. This is a concern because alluvial wells MMW017 and MW-15A both had measured total selenium concentrations that exceeded the drinking water standard (0.13 and 1.99 mg/L, respectively). In addition, based on water levels in the alluvial and Wells Formation monitoring wells, a downward gradient exists. Therefore, selenium impacted alluvial groundwater could impact the underlying Wells Formation regional flow system. The relationship between the alluvial system and the Wells Formation is shown on Sections H, I and R (Drawings 13 and 14). Any further investigation of the Wells Formation west of the mine area will have to consider the alluvium depth and the location of the potential fault. Further investigation of the Wells Formation west of the Ballard Mine appears prudent.

3.2.4 Ballard Mine Data Needs

Impacts to the alluvial system surrounding the Ballard Mine have been documented through sampling of springs and shallow monitoring wells. Further characterization of the alluvial system has been planned using a direct-push sampling system (MWH, 2007b). This program will help define the extent of selenium impacts in the shallow alluvial system. Once completed, an assessment will need to be made as to locations of possible alluvial monitoring well installations. Further, through the characterization of the alluvial system, monitoring wells in the underlying formations can be located in areas that are more likely to be impacted if downward migration from the alluvium is occurring.

It is anticipated that an additional monitoring well in the Dinwoody Formation east of the mine area will be needed to assess if impacts are occurring due to migration from the alluvium. This well should be installed in the Dinwoody Formation below the alluvial/bedrock contact in the less decomposed portion of the unit. Siting of this well should be based on an association with an area of higher impact to the alluvial system. It is estimated that this monitoring well may be as deep as 150 feet.

The presence of impacted alluvial groundwater west of the mine area and impacted Wells Formation in the mine area suggest that the Wells Formation along the western edge of the mine site should be further investigated. Two areas are suggested for consideration for additional Wells Formation monitoring wells. The first is in the vicinity of MW-16A. This area is potentially downgradient of MMW006 and near an apparent east-west structure that may direct flow from the southern edge of the mine area. A second well should be installed 1,000 to 1,500 feet north-northeast of MMW017 to address potential northwestward groundwater flow in the Wells Formation from the mine site along the strike of bedding and structures. Groundwater elevation in the Wells Formation is expected to be between 6,200 and 6,230 ft-AMSL near the mine. The ground surface in the area of potential investigation ranges from 6,325 to 6,350 ft-AMSL. This suggests that the depth to groundwater in the Wells Formation is at most 150 feet along the west side of the mine area.

3.3 HENRY MINE AREA

The Henry Mine plan called for five mine panels or pits along five miles of phosphate outcrop. Pits I and II were the site of the initial mining beginning in1969 near the center of the current mine area, Pit III was the South Henry Continuation, Pit IV was the Center Henry Continuation, and Pit V was the North Henry Continuation (USGS, 2001). The two middle panels (II and IV) at Henry Mine were mined separately, but ultimately joined during mining. These pits are currently designated as MMP041 through MMP044. The Henry Mine is therefore divided into three geographic parts: North Henry (one pit, MMP041), Center Henry (two pits, MMP042 and MMP043), and South Henry (one pit, MMP044), as shown on Drawing 10. Final mining operations were completed at North Henry (MMP041) in October 1989 (USGS, 2001) and final reclamation was completed in 1990.

Waste rock was distributed along the length of the mine in five waste rock dumps (MWD085, MWD086, MWD087, MWD088, and MWD090). The designation of MWD089 as an individual dump was discontinued because during mining, the materials in MWD086 and MWD089 were intermixed from their sources; now the two waste rock dumps are considered to be one continuous dump, designated MWD086.

The Henry Mine is largely reclaimed; including grading, contouring and revegetation of the waste dumps (see Section 1.2.2). Portions of mine pits MMP041 and MMP044 remain as open pits, while MMP042 and MMP043 were backfilled. The pit backfill is graded so that the topography is similar to the pre-mine topography (Drawing 3) and stormwater flow is directed off the backfilled mine pit. The backfill for MMP041 and MMP044 is complete for a portion of the pit, providing positive drainage off of the pit, while the other portion has been left open. Portions of the high walls remain exposed along most of the length of the mine where mine pits have been backfilled. At these locations, the exposed high wall is Wells Formation.

The mine plan was relatively simple compared to the Ballard Mine, because mining was developed along the northeastern limb of the Wooley Valley anticline, and the stratigraphic section is not repeated within the mine area. The areas immediately to the southwest of the mine pits are a ridge formed by Wells Formation, while areas to the northeast of the mine pits are lowlands generally underlain by alluvium, as well as remnants of the Phosphoria Formation, and stratigraphically higher units, like the Dinwoody Formation along ridges. Consequently, the mine pits and related mine dumps are elongate along a northwest-southeast trend parallel to the strike of the Phosphoria Formation, with the pits developed along the hillsides to the southwest (Drawings 3 and 10). As a result of the topographic setting and the placement of the mine pits, surface water runoff and shallow groundwater flow from the pits and waste dumps will tend to be downhill to the northeast until intercepting the lowlands and then flowing along the valley bottoms, generally to the east and southeast.

3.3.1 Shallow Alluvial System

The three portions of the Henry Mine relate to breaks in the anticline limb topography, which affect the surface water and alluvial flow patterns. Each area is discussed separately below.

3.3.1.1 North Henry

In the vicinity of North Henry, there are basically three shallow alluvial systems: two systems exist approximately 2,500 feet to the southwest and to the northeast (see Drawing 10 and Section P, Drawing 18), and a third is located to the east/northeast of the North Henry mine pit through which the Little Blackfoot River flows. Both the alluvial systems to the southwest and northeast are separated from the mine by topographic highs and intervening bedrock (see Section P). Only the alluvial system immediately to the east/northeast of the North Henry Pit is located physically or hydrostratigraphically close enough to the mine area to be a completed flowpath.

The potential flowpath to the shallow alluvial system in this area is east/northeast of waste dump MWD085. There is a small drainage underlain by colluvium (not shown on the geology map), as well as Quaternary Basalt (see Drawing 10). Waste dump MWD085 (see Drawing 10) overlies the head of this drainage and runs along the western flank. It is possible that this valley does contain some saturated alluvium, and therefore, the direct-push program may include some boreholes along this valley upon further field assessment. The surface water flow direction along this drainage would be to the southeast towards the Little Blackfoot River and tributaries. Where the drainages cut the basalt they tend to be incised with very limited amounts of alluvium, especially perpendicular to the stream channels. However, data also suggests that in some areas, the alluvium within these drainages, including the Little Blackfoot River farther to the southeast and southwest may be up to 100 feet thick (Brooks, 1982). Further reconnaissance is needed in this area to determine if a complete alluvial flowpath is potentially present.

Another area that could contain shallow alluvium near the mine area is to the northwest of the North Henry pit. The geologic map (Drawing 10) does not show alluvium in this area. However, there is a small drainage that drains from the northwest corner of the backfilled portion of pit MMP041 down to the northwest onto the Quaternary Basalt, and it is possible that some shallow colluvial/alluvial flow occurs within this small drainage. Only a portion of pit MMP041 is located within this drainage (all other areas drain to the southeast away from this potential flow system), and the external waste dumps are all located in the southeastward directed drainage. This configuration is best illustrated on Drawing 3, as well as Drawing 10). Therefore, impacts to this potential alluvial system from the mine waste are unlikely to occur, as any infiltration to the backfilled and reclaimed pit will not discharge to the colluvium or alluvium. A completed flowpath is not present, and no additional investigation work is warranted in this area.

While not considered shallow alluvium, the other potential component of the shallow (to intermediate) groundwater system near North Henry is the Quaternary Basalt located in the vicinity of the south end of MWD085. The basalt is generally found at the surface, except where locally overlain by younger alluvium or colluvium, and typically follows the topographic lows because the basalt flooded pre-existing drainages. The basalt is generally 50 to over 200 feet at its thickest along the axis of the topographic gap (Brooks, 1982). The southeastern portion of waste dump MWD085 overlies the basalt. Therefore, seepage or infiltration from MWD085 may recharge, and could cause impacts to groundwater within the basalt. Monitoring well MMW004, which monitors groundwater within the basalt at the southeast end of mine dump MWD085, was last sampled in 2006, during which time selenium was detected at 0.002 mg/L (twice the detection limit), suggesting that a significant impact to the flowpath within the basalt probably has not occurred. This well will continue to be monitored to confirm these previous analytical results.

3.3.1.2 Center Henry

Similar to North Henry, there are three shallow alluvial systems in the vicinity of Center Henry, as can be seen on Section B (Drawing 16): two approximately 3,000 to 3,500 feet southwest and northeast of Center Henry, and a third adjacent to the northeastern edge of the mine. The first two of these systems are topographically and hydrostratigraphically separate from the Center Henry mine, and so are unlikely to be impacted (see Section B). One possible exception to this is the two lobes of waste material in waste dump MWD087 that extend to the southwest across the ridge underlain by the Wells Formation. These lobes of waste dump MWD087 are located within two small drainages that drain southwest into the alluvial system located approximately 3,000 feet southwest of Center Henry (Drawing 10). Through this potential pathway, seepage or runoff from waste dump MWD087 could impact this southwestern alluvial system. The northern of these lobes only contains a small amount of waste rock. For the more substantial “valley fill” dump lobe to the south, a direct-push sample will be collected in 2008 near the toe of the dump (MWH, 2007b).

The third alluvial system is composed of Quaternary alluvium and colluvium that fills a narrow, elongate valley that trends parallel to the mined bedrock units and is adjacent to or beneath the mine (Qw on Drawing 10). There is a topographic divide along this valley located near the southern end of waste dump MWD087, such that surface water runoff within this valley will flow northwest or southeast on either side of the divide. Waste dumps MWD086 and MWD088 are located within or adjacent to the alluvial valley northwest of the divide. Waste dump MWD087 is also located adjacent to and within this alluvial valley, but southeast of the divide. Due to their proximity and uphill or overlying location from the alluvial valley, runoff, seepage, or infiltration from these waste dumps will recharge and potentially impact this shallow alluvium. Currently, there are no monitoring points in the alluvium on the northwestern end of the alluvial deposit. There are several direct-push borings planned in this area in 2008 (MWH, 2007b). Selection of the direct-push boring locations will be field located because of the uncertainty associated with the position of alluvium and waste rock in this area.

Additionally, the shallow alluvial system north of MWD088 is underlain by Quaternary Basalt that fills the gap through which the Little Blackfoot River flows (see Drawing 10; Section F on Drawing 25 shows the general stratigraphic and structural configuration in this area.), which is in the same general area as the basalt adjacent to the south end of MWD085 at North Henry. The north edge of waste dump MWD088 sits on top of or is immediately adjacent to the basalt. Consequently, seepage from MWD088 could impact the Quaternary Basalt at this location. Monitoring well MMW003 was thought to have been installed in the Quaternary Basalt, and was most recently sampled in 2006, at which time 0.034 mg/L selenium was detected, indicating potential impacts to the basalt in this area. MMW003 was abandoned in 2007 and monitoring well MMW019 was intended to be installed in basalt downgradient of MMW003; however, basalt was not encountered in that area. Further geologic reconnaissance is needed in this area to further assess this potential flowpath.

Runoff or shallow groundwater flow from waste dump MWD087 or mine pit MMP042, which is southeast of the surface water divide, flows northeast into the above-mentioned alluvial valley, and then to the southeast along the alluvial valley. A cross-section along the axis of this valley and in the direction of shallow alluvial groundwater flow (Section O) is shown in Drawing 19. Monitoring well MMW010 was installed in the shallow alluvium adjacent to waste dump MWD087. This well was sampled in the fall of 2007, at which time it was non-detect for selenium, indicating that impacts to the alluvium have not apparently occurred. These data will be supplemented by additional groundwater sampling during the direct-push sampling program in 2008 (MWH, 2007b).

Just to the southeast of waste dump MWD087, the shallow alluvial valley splits into two tributaries: one drains to the southwest towards Long Valley Creek, and the other drains to the southeast and then northeast into the upper reaches of Lone Pine Creek, as shown on Drawings 3 and 10. As a result of the mining disturbance, the surface water drainage from the mine area is now to the southeastern drainage where previously it appears to have been directed toward the southwest and Long Valley Creek. In addition, the southern end of a backfilled mine pit crosses the former southwestern directed channel (see Section E, Drawing 19). The tributary that drains to the southeast is adjacent to South Henry and so is discussed in more detail in section 3.3.1.3.

Seepage and shallow groundwater flow from the southern end of Center Henry could recharge and potentially impact groundwater within the alluvial system that flows to the southwest towards Long Valley Creek. The backfilled mine pit would have to be completely saturated to the level of overtopping to the alluvial system for flow to discharge off site from this flowpath. This may occur at least seasonally. Monitoring well MMW010 was installed in the alluvial channel upgradient of the backfilled mine pit. A water sample from this well in the fall of 2007 indicated a total selenium concentration of less than the detection limit of 0.001 mg/L. However, flow through the pit backfill, downgradient of MMW010 could impact the alluvial groundwater. In order to test this potential, direct-push boreholes are planned in this area. Pond MSP014 is also present in this area, and in the spring of 2006 had an average selenium concentration of 0.071 mg/L. It is possible that this pond receives some direct surface water runoff from waste, as well as direct waste rock seepage. The spatial relationship between MSP014 and the waste rock will be further evaluated in 2008. This area will also be included in the direct-push investigation, which may provide some insight into the migration of selenium to the pond.

3.3.1.3 South Henry

There is one shallow alluvial groundwater system that could be impacted by South Henry. The alluvial system is located primarily to the northeast of the mine and is partially overlain by waste dump MWD090 (see Drawing 10). The relationship between open pit MMP044, waste dump MWD090, and the shallow alluvium is depicted on cross-section N (Drawing 17). As can be seen on Section N, seepage from waste dump MWD090 would directly recharge the alluvial system, and then flow as shallow groundwater to the northeast into the upper reaches of Lone Pine Creek.

A series of springs (headwater stream stations) are present in the upper reaches of Lone Pine Creek (MST058, MST064 and MST276) that likely represent a discharge area for shallow groundwater within the alluvium beneath waste dump MWD090. The shallow water level in MMW014 (2.9 feet bgs) suggests that the well is in the same flow system as the springs. The total selenium values of the three springs ranged from 0.005 to 0.020. Another spring (MSG002) is present just downhill of waste dump MWD090, as shown on Section N, but has been dry since at least 2002. Dump seep MDS022 is located between MWD090 and MMW014. Total selenium concentrations in the seep have ranged from not detected (<0.001 mg/L) to 0.008 mg/L. Monitoring well MMW014 was installed into the older alluvium (Qw) just downhill of waste dump MWD090 (see Section N), and was sampled in fall 2007, at which time total selenium was not detected, with a detection limit of 0.001 mg/L. These data suggest that impacts to the shallow alluvium in this area are not present with respect to groundwater quality standards.

3.3.2 Dinwoody and Thaynes System

The Dinwoody and Thaynes Formation are mapped to the northeast of the Henry Mine, but are not present within the interior, or southwest of the mine (see Drawing 10). The Dinwoody Formation outcrops along a ridge northeast of the mine. Then the Thaynes Formation is mapped along a second ridge farther to the northeast with an intervening alluvial valley along the trend of the Henry Thrust fault.

All of the mine pits are west of and are hydrostratigraphically separated from the Dinwoody and Thaynes Formations, due to the presence of the upper Phosphoria Formation, and none are in direct contact with the Dinwoody or Thaynes Formations. In order for seepage from the mine pits to flow to and recharge the Dinwoody Formation (closer to the mine than the Thaynes Formation), it would have to flow across bedding through the Phosphoria Formation and into the Dinwoody Formation. The Phosphoria Formation has a low hydraulic conductivity perpendicular to bedding and is generally an aquitard; therefore, seepage from the mine pits is unlikely to impact the Dinwoody or Thaynes Formations.

On the other hand, some portions of the waste rock dumps are in direct contact with (overlie) the Dinwoody Formation (see Drawing 10). In most areas, the dumps are physically separated from the Dinwoody Formation due to intervening alluvial material (see Sections B, E and N, Drawings 16, 19 and 17). However, small portions of waste dumps MWD085, MWD086/MWD087 and MWD088 are in direct contact with the Dinwoody Formation without significant intervening alluvial (colluvial) material. A portion of waste rock dump MWD086 was reclaimed such that the surface was not graded to ensure positive drainage allowing rainwater or snowmelt to pool on the dump surface, infiltrate directly into the waste dump, and potentially impact the Dinwoody Formation. Therefore, monitoring well MMW022 was installed in the Dinwoody Formation, adjacent to the northeastern lobe of MWD086 where it is in direct contact with the Dinwoody Formation (Drawings 10 and 16). This location was considered a "worst case" condition for the potential waste rock – Dinwoody Formation flowpath at the Henry Mine.

Well MMW022 was sampled in fall 2007, at which time total selenium was detected at 0.016 mg/L, indicating some impact to the Dinwoody Formation. Due to the presence of the Henry Thrust Fault, as well as portions of the middle of the Dinwoody Formation section with low permeability, it is unlikely that groundwater within the Dinwoody Formation will flow to the northeast into the Thaynes formation. It is however possible that groundwater within the Dinwoody Formation flows along bedding and discharges further up the stratigraphic section in the down-dip direction. The water level within MMW022 is approximately at 6,420 ft-AMSL whereas the ground surface elevation in the alluvial area to the northeast is approximately 6,340 ft-AMSL. An additional seep and spring survey will be conducted in 2008 to evaluate whether groundwater discharge is occurring in the drainage to the northeast of MMW022. Since the Henry Thrust fault is likely a barrier to groundwater flow, groundwater within the Dinwoody Formation could discharge along the fault as springs. Springs have not been observed along the Henry Thrust fault, and if this area were to be investigated a direct-push sampling program could be used. However, given the concentration observed in MMW022, which is below the drinking water limit of 0.05 mg/L, investigation this distant from the potential source is not warranted.

A third possibility exists. The groundwater flow in the Dinwoody may also have a component of flow to the northwest along the strike of the bedding and folding. A shallow Dinwoody Formation well near the Little Blackfoot River could be used to assess this potential flowpath.

3.3.3 Deep Wells Formation System

The Wells Formation, which is considered a regional aquifer, outcrops to the southwest of the Henry Mine, adjacent to the high-wall of all of the Henry mine pits, The ridge to the southwest of the Henry Mine, which is underlain by Wells Formation (Drawing 10) is an area of recharge to the Wells Formation (Brooks, 1982). A major discharge area for the Wells Formation occurs near the town of Henry to the northwest (Mayo, 1982), indicating that regional groundwater flow within the Wells Formation is to northwest in the direction of bedding strike. Therefore, the hydrogeological conceptual model suggests that groundwater that originates in the Henry Mine area flows northwest along strike. Groundwater flow within the Wells Formation could occur along strike to the southeast, however, this does not appear to be occurring due to a higher hydraulic potential to the southeast, as evidenced by the discharge area near Henry. Additionally, groundwater flow to the southeast would be impeded due to the presence of thrust faults to the southeast, which are typically barriers to groundwater flow. Measuring a selenium impact in the springs at Henry is unlikely as the water discharging from the springs has been dated at approximately 20,000 years old (Mayo, 1982).

Two monitoring wells are installed in the Wells Formation to monitor for potential impacts from the Henry Mine. One (MMW011) is located north of the northwest end of MMD088 (Center Henry), and the other (MMW023) was installed through the base of open pit MMP041 into the Wells Formation. Preliminary survey data for these wells appear to support the northwestward flow direction. The springs near Henry discharge at approximately 6,150 ft-AMSL. The preliminary data appear to suggest the well closest to the spring (MMW023) has a water level of approximately 6,160 ft-AMSL, and MMW011 is in the range of 6,170 ft-AMSL. These data help validate the conceptual model. However, these data were collected in mid-winter and need to be verified in the spring of 2008.

Both monitoring wells were screened across the top of the Wells Formation, as can be seen on the drilling logs included in Appendix A. Due to the steep dip of the Wells Formation along the extent of the Henry Mine (up to 70 degrees), it is difficult to find locations to drill into the Wells Formation that are at a reasonable depth (e.g., less than 700 feet bgs). While drilling well MMW023, the top of the Wells Formation was observed at approximately 352 feet below the bottom of pit MMP041, while the water level in the well was measured at 105 feet below the bottom of the pit. The water level in well MMW011 within the Wells Formation was measured at approximately 90 feet bgs, which is 190 feet beneath the bottom of the north end of waste dump MWD088, indicating that the pits and dumps are hydrologically higher than the Wells Formation.

Monitoring wells MMW011 and MMW023 were last sampled in fall 2007. Well MMW011, located approximately 400 feet northwest of waste dump MWD088 along the strike of bedding, was non-detect for total selenium (<0.001 mg/L) indicating that impacts to the Wells Formation from Center Henry have not occurred at this location. Well MMW023, located directly beneath and down-dip of the North Henry pit MMP041 contained 0.003 mg/L of total selenium, indicating a potential impact beneath North Henry may have occurred (0.003 mg/L is only three times the reporting limit, and well below the MCL of 0.05 mg/L).

Currently, there are only two groundwater monitoring wells installed within the Wells Formation at the Henry Mine. As mentioned above, it is difficult to find suitable Wells Formation well locations, due the steep dip of the formation. However, the conceptual model indicates flow to the northwest toward the springs at Henry. Preliminary survey data and water levels support the conceptual model but need to be confirmed. Assuming the conceptual model is correct, these wells are ideally located on the downgradient side of the mine along the strike of the Wells Formation.

3.3.4 Structural Flow System

On the northern end of the Henry Mine, between MMP041 and MMP043, there is a gap in the ridge and an apparent deflection in the geologic units. The Little Blackfoot River flows through this gap. In addition, basalt flooded through the gap in the geologic past (see Drawing 10). There are no significant structural features mapped at this location, as suggested by both the gap and apparent deflection in the geologic units.

When observed on two-dimensional maps, map patterns such as the apparent deflection seen in the North Henry mine can be related to the manner in which the three-dimensional (dipping) bedding contacts intersect the two-dimensional ground surface. For example, a steeply dipping geologic unit that intersects a hillside will tend to inscribe an arcuate pattern as seen in map view that looks like a fold or other structurally related feature or offset. Consequently, further geologic data were reviewed to determine if the apparent feature seen at the North Henry mine is related to a distinct, local geologic structure or merely the relationship between the strike and dip of the bedding and the topographic relief. Specifically, Monsanto pre-mine geologic mapping data from 1966 were reviewed. The additional map data indicated that the strike of bedding north of the Little Blackfoot River ranges from N64ºW to N72ºW (four measurements), while south of the river it ranges from N29ºW to N53ºW (five measurements). The dip of the bedding north of the river ranges from 59º to 65ºNE, while south of the river it ranges from 42º to 73ºNE (Table 3-2). This variation in strikes and dips north versus south of the Little Blackfoot River is consistent with a structural feature separating the mine areas north and south of the River.

TABLE 3-2
STRIKE AND DIP OF BEDROCK IN THE HENRY MINE AREA NORTH AND SOUTH OF THE LITTLE BLACKFOOT RIVER

North of Little Blackfoot River	South of Little Blackfoot River
N65W, 63NE	N30W, 70NE
N64W, 59NE	N28W, 73NE
N65W, 65NE	N53W, 57NE
N72W, 61NE	N51W, 71NE
----	N29W, 42NE

Source Map: Henry Property, Monsanto Chemical Company, Scale 1"=200', Contour Interval = 5', Geology by W.L. O'Toole, November 24, 1966.

A structure in this area was not identified on the previous geologic mapping in the area. If a distinct structural feature exists in this area, it is concealed beneath the Quaternary Basalt that flooded through the gap. Where the Little Blackfoot River cuts through the gap, the underlying geologic units are exposed; however, the small exposed slice north of the river appears to be consistent with the geology south of the river, indicating that if a distinct structural feature is present, it is located north of the river beneath the basalt flow.

The proposed structural feature could either be a fault with relatively minor displacement or a fold. Any efforts to locate the structural feature beneath the basalt would be completely blind. Because the proposed structure apparently pre-dates the basalt and is located beneath it, impacted water from waste dumps or mine pits can not directly infiltrate into the feature. Therefore, any impacted groundwater would have to move laterally to the structure. Four wells have been installed in this area to address this potential flow path – MMW011 in the Wells Formation, MMW019 in the shallow bedrock horizon, and MMW003 and MMW004 in the basalt (Drawing 10). Total selenium above the MCL (0.05 mg/L) has not been detected in this area (Table 2-1). However, total selenium has been detected in MMW003 at 0.034 mg/L. It appears unlikely that the structure provides a significant pathway and given the difficulty in investigating the feature, further investigation is not recommended. However, if other pathways are found to be significantly impacted that could flow to the structure, then further investigatory effort may be warranted.

To the south of South Henry, there is a thrust fault that displaces the bedrock units and offsets the surface expression of the Wells Formation. This is a thrust fault that is likely a barrier to groundwater flow, and as discussed above, is a contributor to the hypotheses of northwest flow of groundwater within the Wells Formation. It is unlikely that significant flow will occur along or across the fault to the southeast.

Other mine faults have been mapped in the Henry Mine area cutting through the stratigraphic units approximately perpendicular to strike. These frequent faults, however, show relatively minor displacement, are narrow fractures, and are likely only locally present. Such faults and fractures contribute to the bulk hydrogeologic character of the bedrock unit and should be characterized as such. However, it is through these common minor features that flow between individual beds, perpendicular to the bedding, could occur.

It is recognized that faulting perpendicular to bedding may compartmentalize flow within the Wells Formation so that flow is not entirely along strike. However, a low permeability fault surface could deflect flow or simply retard it. Conceptually, the principal concern with these faults is that a well like MMW023 on the downgradient end of the mine may in fact only be seeing flow from a small area downgradient of a cross cutting fault. Water level response monitoring between MMW011 and MMW0023 on either side of the probable fault along the Little Blackfoot River will provide some information on the degree to which the fault may act as a flow barrier. A fault with a similar amount of potential displacement is not observed elsewhere along the strike of the Henry Mine, but should a significant flow barrier be indicated, the conceptual model would need to be revised accordingly.

3.3.5 Henry Mine Data Needs

Impacts to the alluvial system surrounding the Henry Mine have not been observed based on sampling of springs and shallow monitoring wells. However, some areas are not well understood in terms of whether shallow alluvium is present, the local hydrogeologic setting, and how the alluvial system relates to the primary mine features (backfilled pits, open pits, and waste dumps). Therefore, further characterization of the alluvial system has been planned in some areas using geologic reconnaissance and a direct-push sampling program (MWH, 2007b). This program will help better define the location of saturated alluvium, colluvium, and weathered bedrock, and further evaluate whether selenium impacts to the shallow alluvial system have occurred. The direct-push program may include the installation of direct-push pre-packed screens at select locations that can be completed for on-going shallow groundwater monitoring.

The shallow portion of the Dinwoody Formation has been demonstrated to be impacted by selenium near Center Henry. This area has the greatest potential for an impact to the Dinwoody Formation based on the amount of waste rock placed on the Dinwoody Formation, as well as the configuration of the waste dump surface. Only minor amounts of waste rock overlie the Dinwoody Formation in other areas, and in these areas the waste dump surface has better grading to develop positive drainage off the reclamation area. Monitoring well MMW022 is sufficient to monitor impacts to the Dinwoody Formation and additional investigation of the intermediate groundwater system within the formation is not necessary at this time. However, given the orientation of the Dinwoody Formation bedding and the conceptual flow direction away from the mine area toward Lone Pine Creek to the northeast, a further spring survey should be conducted to confirm previous reconnaissance in this area.

The spring survey will focus on the heavily vegetated drainage immediately to the northeast of MMW022 down to the trace of the Henry Fault. If a spring is located, it is likely a discharge point for the intermediate Dinwoody Formation flow system that originates in the Henry Mine area, and the spring would be sampled. The other potential flow direction in the Dinwoody Formation is to the northwest toward the Little Blackfoot River. This potential flow path can be addressed through the installation of a well into the Dinwoody Formation, near the river.

There are no areas where impacts to the Thaynes Formation are likely to occur, as none of the waste dumps or pits are in direct contact or overlie the Thaynes Formation. Furthermore, surface water runoff and shallow groundwater flow cannot impact the Thaynes Formation as it is separated from the mine by intervening ridges and valleys. Therefore, additional investigation of the Thaynes Formation is not required.

The most significant data need associated with the regional flow system in the Wells Formation is surveyed water level data from MMW011 and MMW023 to help validate the conceptual model of flow along strike to the spring near Henry. These data were not obtained before access was limited by snow in 2007.

Two significant structural features exist at the Henry Mine. On the northern end of the mine, there is a gap in the ridge and an apparent deflection in the geologic units, but no significant structural features have been mapped at this location. Any efforts to locate the structural feature beneath the basalt would be blind and require drilling through the basalt to an unknown depth. Because the proposed structure apparently pre-dates the basalt and is located beneath it, impacted water from waste dumps or mine pits cannot directly infiltrate into the feature. It appears unlikely that this potential structure provides a significant pathway, and given the difficulty of investigating it, further investigation is not recommended. However, if other pathways are found to be significantly impacted that could flow to the potential structural feature, further investigation in the area will be considered.

The other significant structural feature is two thrust fault splays at the south end of the mine that displace the bedrock units and offset their surface expression. These faults are likely a barrier to groundwater flow and contribute to a higher potentiometric surface at this end of the mine and northwest flow of groundwater within the Wells Formation. It is unlikely that significant flow will occur along or across these faults to the east or southeast. Since this feature is located on the upgradient end of the mine, additional investigation in this area is not warranted.

3.4 ENOCH VALLEY MINE AREA

The Enoch Valley Mine, like the Henry Mine, is developed along an anticline limb and is relatively linear running along a northwest trending exposure of the Phosphoria Formation. The mine was operational between 1989 and 2003. The Enoch Valley Mine is largely reclaimed with the exception of a partially backfilled mine pit near the center of the mine. In general, the mine waste dumps and the backfilled mine pits can be characterized as well graded and well vegetated. Additional detail on the Enoch Valley Mine is provided in MWH (2007a). The current conceptual models for the Enoch Valley hydrogeology are described in the following sections and are illustrated on the geology map (Drawing 10), Section A, which illustrates the broader geologic section (Drawing 20), and Sections D, J, K, L and M, which provide more detailed information (Drawings 21 through 24). Ponds and seeps directly associated with the mine waste areas contain selenium concentrations at levels that suggest impacts to groundwater are possible (e.g., dump seep MDS026 has an average total selenium concentration of 0.12 mg/L (MWH, 2007a)). However, groundwater wells and more distal springs indicate that impacts to groundwater do not extend much beyond the near-surface in the vicinity of the mine and waste rock facilities as indicated by Wells Formation monitoring well MMW009 and deeper alluvial system wells MMW007, MMW008 and MMW013, which were all found to have total selenium concentrations of less than or equal to 0.002 mg/L in 2007.

3.4.1 Shallow Alluvial System

Similar to the Henry Mine, opportunities for off-site impacts to the alluvial flow system are relatively few. This is because of the linear configuration of the mine where much of the mine sits in a small valley that parallels the geologic formations. There is a hydrologic divide near the center of the mine. The northern portion of the mine drains toward Lone Pine Creek and the Little Blackfoot River, whereas the center and southern portions drain toward Rasmussen Creek and

East Fork of Rasmussen Creek, and then Angus Creek (Drawing 10). Conceptually, if the alluvial groundwater is impacted by selenium or other COPCs, then the associated creeks may receive impacted discharge. Given the apparent low-permeability of the alluvial material in the Enoch Valley Mine area as indicated by the drilling done in 2007 (Section 2.2.1.1), direct exposure through a water well seems less likely. This is because construction of a well with sufficient groundwater yield to be of practical use from the alluvial material seems unlikely. The first potential for a usable water bearing zone appears to be in the uppermost portion of the underlying bedrock formation.

Conceptually, impacts to the Enoch Valley alluvial systems may be less than at Ballard. In general, the waste rock areas of the Enoch Valley Mine are well-reclaimed with well-established grasses and good slope grading. These factors will reduce infiltration into the waste rock. However, the existence of impacted stormwater ponds on the waste rock in the southern portion of the mine may enhance infiltration through the waste rock (e.g., MSP017 through MSP021). Another factor in evaluating the Enoch Valley alluvial flow system is the apparent low permeability of the alluvial material. It was found during the 2007 investigation that the alluvial material was clay and silt-rich indicating a low overall hydraulic conductivity. This favors dump toe seepage as discussed in Section 3.1.1 opposed to infiltration into the alluvial system. The hydraulic conductivity of the alluvium has not yet been tested, and this is a data gap to be addressed in 2008.

Alluvial flow in the northern portion of the mine is primarily captured by three ephemeral drainages. The largest of the drainages is located above spring station MST061 and now contains monitoring well MMW012 (Drawing 10). The other minor drainages are located to the north. Section L is oriented approximately down the larger of the drainages through MMW012 and toward agricultural well MAW003 (Drawing 23). The conceptual flow system for this area includes waste rock seepage potentially infiltrating into the alluvial system and flowing westward toward Lone Pine Creek as illustrated in Section L.

This northern alluvial flow system was tested through the installation of MMW012 in 2007. However, it was found that the alluvial flow system down to the Dinwoody Formation contact was dry, and during the fall of 2007 the well did not produce any water. The well was not completed at a deeper depth within the Dinwoody Formation to test the hypothesis that the alluvial system, like the overlying surface water system, is seasonal.

The waste rock above MMW012 is well reclaimed with slopes that encourage runoff during spring snowmelt. As such, selenium impacts at MMW012 are not expected to be as likely as some other areas. In the spring of 2008, this will be further tested by monitoring MMW012 and by the implementation of the Direct-Push Sampling Investigation (MWH, 2007b). The direct-push investigation will include additional sampling points in the drainage containing MMW012, as well as in the two drainages to the north.

Alluvial flow from the center and southern portions of the mine will report to Rasmussen Creek and the East Fork of Rasmussen Creek. The most direct impacts are likely to the East Fork of Rasmussen Creek where the channel runs along and underneath the southern mine waste area (MWD092) (Drawing 10). Mine waste overlies some smaller tributary channels feeding Rasmussen Creek, most notably at MDS025. Sections D, J and K illustrate the alluvial flow system in the southern area (Drawings 21 and 22).

The alluvial system in the southern area of the mine was evaluated through the drilling of monitoring wells MMW007, MMW008 and MMW013 in 2007. Similar to the MMW012 location in the northern Enoch Valley Mine area, the alluvium did not yield significant groundwater at any of the three well locations in the southern area. However, all three wells in the southern area were advanced into the shallow Dinwoody Formation where groundwater was encountered. As discussed previously, this shallow bedrock system is considered a continuation of the alluvial system and primarily represents flow along the upper decomposing bedrock contact.

The positions of MMW007 and MMW008 are schematically shown on Section D in cross section (Drawing 21), and in plan view on Drawing 10. The total selenium concentrations measured in these two wells were 0.002 mg/L and <0.001 mg/L, respectively. Monitoring well MMW013 is projected onto Section K (Drawing 22). The total selenium concentration measured in MMW013 was <0.001 mg/L. Based on these results, the higher yielding Dinwoody Formation contact does not appear impacted by water percolating through the waste rock. However, it still remains that there may be lower yielding shallow alluvial flow that may be seasonal. The direct-push sampling investigation that will be completed in the spring of 2008 will assess this potential component of the alluvial flow system.

<u>The water yield and water levels in both MMW007 and MMW008 rose substantially once the more permeable weathered bedrock was encountered. This suggests that the water at that depth may be confined or semi-confined by the overlying clayey alluvium. Alternatively, an unconfined water table condition may be present and the depth to water may be indicative of the depth to water in the alluvium. The 2008 direct push investigation will also potentially provide data to help resolve this issue.</u>

3.4.2 Intermediate Dinwoody and Thaynes System

The Dinwoody Formation outcrops along the southwestern portion of the Enoch Valley Mine. This outcrop area likely represents a recharge area for an intermediate groundwater flow system in the Dinwoody Formation. However, the discharge location for this flow system has not been identified. A flow system with discharge along the Henry thrust fault is conceptually reasonable (see Section B, Drawing 16); however, the trace of the thrust fault has not been observed to be a locus of spring discharge. Discharge to the northwest and southeast is also a possibility. In these areas, the discharge could be to the Lone Pine Creek or Angus Creek alluvial systems. Springs in these areas have not been located that may be associated with this system.

The area of most probable impacts to the Dinwoody Formation is in the southern portion of the mine. In this area, the recharge area for the Dinwoody Formation is overlain by the MWD092 waste rock dump. The relationship of the Dinwoody Formation and the waste dump in this area is shown on Sections D, J and K (Drawings 21 and 22). Monitoring wells MMW007, MMW008 (on the southeast end) and MMW013 (on the southwest side) have all been installed in the uppermost portion of the Dinwoody Formation. These wells may be more closely associated with the alluvial system. However, the total selenium concentrations ranged from 0.002 mg/L to less than the detection limit of 0.001 mg/L, and the lack of significant impact to the shallower system suggests limited potential for an impact to the deeper system. Nonetheless, the deeper system has not been directly tested. It needs to be considered that water infiltrating the Dinwoody Formation directly below the waste rock may infiltrate to a deeper level.

For the majority of the northern portion of the mine area there is not a source to the Dinwoody Formation. The waste rock is confined to the mine pit backfill and exposure to the Dinwoody Formation is limited (see Drawing 10). In the case of the Enoch Valley Mine, the Dinwoody Formation was not exposed in the pit walls. There are, however, external waste dumps on the northernmost end of the mine located on Dinwoody Formation and colluvium overlaying Dinwoody Formation. Sections L and M (Drawings 23 and 24) illustrate the relationship between the dump material and the Dinwoody Formation. No wells have been installed into the Dinwoody Formation in the northern area, and the northern area could present an opportunity to further evaluate this potential exposure pathway. However, compared to the southern portion of the mine, the potential source area is smaller compared to Dinwoody Formation exposure, and the reclaimed slopes are steeper, which will reduce potential infiltration. In addition, the southern area contains stormwater ponds on the reclaimed waste rock surface. Therefore, impacts in the southern area would be more likely.

The Thaynes Formation can also be a component of local or intermediate flow systems. At the Enoch Valley Mine, the Thaynes Formation is not in direct contact with any sources (see Section K, Drawing 22 for an example). The only potential for impacting a flow system in the Thaynes Formation is therefore indirect, such as impacted alluvium that overlies the unit. At this time, such indirect sources have not been indicated, and the flowpath between mine-related sources and groundwater systems in the Thaynes Formation is not complete.

3.4.3 Deep Wells Formation System

The Wells Formation outcrops primarily east of the Enoch Valley Mine on the opposite side of the Enoch Valley Fault (Drawing 10). The Enoch Valley Fault displaces Wells Formation against Wells Formation in the mine area as shown on Section A (Drawing 20). The exposure of Wells Formation east of the mine represents the core of the Snowdrift Anticline and likely represents a significant recharge area for the regional groundwater flow system. The elevation of this area is just above 7,000 ft-AMSL over the majority of the area. Down-geologic-dip to the southwest, the Wells Formation rapidly plunges to the core of the adjacent syncline at as much as 3,000 feet below the ground surface and less than 4,000 ft-AMSL (see the left side of Section A, Drawing 20, and right side of Section B, Drawing 16). In the majority of the mine area, the Wells Formation strikes northwesterly and dips steeply at approximately 60 degrees. However, there is a flexure in the northern portion of the mine, and the strike swings approximately 20 degrees further west and flattens to approximately 45 degrees (Drawing 10).

The conceptual model for flow in the Wells Formation in the mine area is for flow from the recharge area east of the mine and then generally to the west beneath the Enoch Valley Mine towards the Henry thrust fault. This assumes that the normal Enoch Valley fault does not function as a flow barrier. There needs to be a northwest or southeast component to the flow due to the structural grain of the region. Thrust faults commonly act as a flow barrier, in which case, it would deflect flow. If the thrust fault is not a flow barrier, then the effect of the Wells Formation recharge area to the west of the Henry Mine will nonetheless cause a northwest or southeast flow along the axis of the syncline.

Regional flow from the Enoch Valley Mine area, along the Henry thrust fault, toward the springs at Henry (elev. 6,130 ft-AMSL) is a possible flowpath (Drawing 10). It is also possible that flow is to the north of Henry to Wells Formation springs associated with the Enoch Valley Fault. The sinkhole spring of Mayo (1982) is one possible discharge location (located approximately 18 miles to the northwest of the mine at approx. 6,200 ft-AMSL). Dating of water issuing from these springs indicates that the water is on the order of 20,000 years old (Mayo, 1982). Potential discharge locations to the southeast of the Enoch Valley Mine have not been identified.

The Wells Formation is largely only in contact with mine wastes in the footwall of the backfilled mine pits at the Enoch Valley Mine. Mine waste rock dumps generally have not lapped over onto the Wells Formation exposures east of the mine (see Sections K, L and M, Drawings 22, 23 and 24). The most likely source of potential selenium impact to the Wells Formation is, therefore, infiltration through a backfilled mine pit as discussed in Section 3.1.2. The waste dumps have lapped over onto the Dinwoody Formation in areas west of the mine pits.

Flow to the northwest and southeast along strike of the Wells Formation represents a more likely exposure scenario for potential groundwater receptors. In these directions, the Wells Formation may be reached with a well of reasonable depth. Down-dip to the southwest, the Wells Formation deepens rapidly, and the only potential receptor would be a deep municipal type water well, which is not likely in this area given the distance to a large municipal area and many other shallower locations where the regional flow system may be reached.

A goal for the 2007 field program was to specifically test the Wells Formation flowpath from a backfilled mine pit. This was done with the installation of MMW009. The position of MMW009 downgradient of a backfilled mine pit is illustrated on Section M (Drawing 24). The relatively high head in MMW009 at approximately 6,520 ft-AMSL supports the supposition of a substantial recharge area for the regional Wells Formation flow system to the east, and that the normal Enoch Valley Fault is not a flow barrier. The concentration of total selenium measured in MMW009 in the fall of 2007 was 0.001 mg/L (at the detection limit; see Section 2.3.4).

The position of MMW009 is in the flowpath from the mine area both in a down-dip, southwest, direction, as well as in a northwest direction along the structural grain. Therefore, MMW009 is well positioned to monitor for impacts to the regional flow system. In part, MMW009 was positioned at its location because of the flattening of the dip of the Wells Formation to approximately 45 degrees in the north end of the mine. To the southeast of MMW009, the dip becomes steeper to approximately 60 degrees. This becomes significant in that the Wells Formation cannot be reached with monitoring wells less than 800 to 1,200 feet deep without drilling directly through the mine pit backfill (see Section K, Drawing 22). Because of the large volume of mine waste contained in the backfill, and because the mine pit will focus any infiltration and potentially pond backfill pore water, drilling through a backfilled mine pit to reach the Wells Formation is not recommended.

A more useful location for additional monitoring of the regional flow system in the Wells Formation may be to the southeast of the mine. This would address the possibility of a southerly component to the regional flow system, and also address a flow direction with more likely potential receptors, whether a deep water well, or indirectly through subsurface discharge to the alluvial system.

A couple of wells have been drilled in the area southeast of the Enoch Valley Mine. The Agrium production well MPW006 appears to have been installed and screened in the Wells Formation (Section J, Drawing 21). However, the driller's log (included in MWH, 2007a) indicated that a portion of the well is also screened above the Wells Formation. The second perforated section of the well is possibly in the Phosphoria Formation, but the log is not sufficiently detailed to confirm this. Regardless, MPW006 was sampled in the spring and fall of 2004 with measured total selenium concentration less than the detection limit of 0.001 mg/L in both events (MWH, 2007a).

Agricultural well MAW005 also appears to have been installed in the Wells Formation to the southeast of the mine along the strike of the Wells Formation (Section J, Drawing 21). The well drill hole appears to have encountered 70 feet of limestone in the bottom of the drill hole. However, the well was only perforated in the upper 30 feet of the limestone. The remaining 50 feet of perforation appears to have been in the alluvium (MWH, 2007a). Well MAW005 was also sampled spring of 2004. The total selenium concentration measured in MAW005 was less than the detection limit of 0.001 mg/L.

The conceptual model and data collected to date suggest that selenium impacts to the regional Wells Formation flow system are not pervasive and may not be present. Monitoring well MMW009 was specifically installed in the Wells Formation downgradient from a backfilled mine pit at the Enoch Valley Mine. Based on sampling in 2007, it appears that the Wells Formation is not impacted in this area. The water quality data from MPW006 and MAW005 indicate that selenium impacts to the Wells Formation are not pervasive in the potential southeasterly directed regional flowpath. These data are not definitive, however, because both wells also draw water from other units. Further characterization of the Wells Formation to the southwest of the mine, down-geologic-dip toward the syncline, may not be practicable because of the steep dip of the Wells Formation and the excessive drilling depth needed to position monitoring wells downgradient of potential sources. However, because of these factors, the regional flow system in this area is also not likely to be a usable groundwater resource with potential receptors.

3.4.4 Structural Flow Systems

As noted in the previous section, there is a flexure in the northern half of the mine where northward the strike of the beds trends more westward and the dip shallows. It has not been determined how much of this change in strike and dip is due to simple folding or how much faulting is involved. To the extent that faulting is present, a large offset does not occur as indicated by the mine configuration and the regional geologic mapping (Drawing 10). As there is not a significant displacement of units across the structure, it is not likely to provide a flow pathway more extensive than otherwise exists. However, further characterization of this area is recommended in the field during 2008.

3.4.5 Enoch Valley Mine Data Needs

During the 2008 field season, the most significant activity to evaluate the alluvial flowpath at the Enoch Valley Mine will be the implementation of the Direct-Push Sampling Investigation (MWH, 2007b). This will address data gaps in a number of areas. Currently, the alluvial system has been assessed through the installation of four new monitoring wells that do not indicate impacts to the alluvial system. However, three of the locations may not address the shallowest portion of the alluvial system, and the four locations did not locate alluvial groundwater. To supplement the data from these wells, the direct-push program will be implemented in the spring when the alluvial water levels should be higher. The direct-push program will provide greater spatial coverage.

The shallow portion of the Dinwoody Formation has been demonstrated not to be impacted by selenium in the southern portion of the Enoch Valley Mine. It is this area that there appears to be the greatest potential for an impact to the Dinwoody Formation based on the amount of waste rock placed on the Dinwoody Formation. The deeper flowpath in the Dinwoody Formation that originates beneath the waste rock pile has not been investigated. Two wells on the southeast and southwest side of the mine into the Dinwoody Formation can be used to evaluate this flowpath. Similar data has not been developed for the northern end of the mine. However, the amount of waste rock placed on the Dinwoody Formation is much smaller, and based on the reclamation with steeper slopes, the potential for an impact appears much smaller.

The most significant component of the Wells Formation regional flow system from a potential receptor perspective is flow to the northwest or southeast along the structural grain. On the northwest end, MMW009 helped address this data gap, as well as, flow to the southwest down-dip. To the southeast, two wells are located in this area and both have intersected the Wells

Formation. One of these, MPW006 may be usable for collecting a discrete sample from the Wells Formation if the two perforated sections can be isolated. This option needs to be evaluated versus installation of a new well in this flowpath. Installation of monitoring wells west of the mine is not recommended at this time given the required depth of any wells installed west of the southern and central portions of the Enoch Valley Mine, and the results from MMW009.

The structural feature in the northern portion of the mine needs to be evaluated in the field and through review of any geologic records specific to the area that can be located. At this time, this is not thought to be a significant hydrogeologic feature. However, the features character needs to be further assessed.

3.5 DATA GAPS MATRIX

The discussion presented in the previous sections is summarized in the data gap matrix tables (Tables 3-3, 3-4 and 3-5). Each table represents one of the mine areas and identifies the relevant flowpaths, sources related to the flowpath, if the flowpath is complete and other relevant data. The preceding text focuses largely on detailed discussion of areas with completed flowpaths. The following tables also summarize incomplete flowpaths. The tables are also referenced back to specific statements in the Agency's data gap memorandum (IDEQ, 2007a). However, more general agency statements may not be referenced.

The data gap matrices are not source area based but are pathway based. To some extent, the boundaries between different waste rock units and some mine pits is arbitrary and is often not based on physical separation. The waste rock facilities at the mines are not directly comparable to waste facilities at an industrial facility, for example. A method of organization where each pathway is identified and those factors relevant to the pathway is therefore presented. However, similar pathways may be listed separately at a mine if there is physical separation, such as a surface or groundwater divide (e.g., east, core and west Ballard Mine areas).

TABLE 3-3
DATA GAP MATRIX FOR THE BALLARD MINE

Conceptual Flowpath	Source Type	Location/ Potential Sources	Completed Flowpath	Agency Data Gap (item #)	Wells in Flowpath	Other Existing Data	Diagrams Illustrating Conceptual Model	Data Gap	Action to Address Data Gap	Note or Comment
Local – Alluvial/Colluvial	Waste Dump	Eastern Mine Area MWD084 MWD082	Yes	27, 28, 29	<u>Monitoring Wells</u> MMW018 (0.029 mg/L T-Se)	<u>Springs</u> MST094 (0.017 mg/L T-Se) MST095 (0.11 mg/L T-Se) MST096 (0.041 mg/L T-Se) MSG004 (0.018 mg/L T-Se) MSG005 (0.0044 mg/L T-Se) MSG006 (0.25 mg/L T-Se)	Sections C, S and T (Drawings 12 and 15), and Ballard Geology Map (Drawing 11)	Extent of selenium impacts in alluvial system is not well understood.	Area to be included in Spring 2008 Direct-Push Sampling Investigation.	
		Western Mine Area MWD083 MWD080	Yes	31, 32, 34	<u>Monitoring Wells</u> MW-15A (0.81 - 1.99 mg/L T-Se) MW-16A (0.049 – 0.11 mg/L T-Se) MMW017 (0.13 mg/L T-Se)	<u>Springs</u> MST067 (0.092 mg/L T-Se) MST069 (0.52 mg/L T-Se)	Sections C, H, I, and R (Drawings 12, 13 and 14) and Ballard Geology Map (Drawing 11)	Extent of selenium impacts in alluvial system is not well understood.	Area to be included in Spring 2008 Direct-Push Sampling Investigation.	
		Core Mine Area MWD093 MMP036	No	30	None	<u>Springs</u> MDS030 (0.55 mg/L T-Se) MDS031 (0.38 mg/L T-Se) MDS032 (0.40 mg/L T-Se) MDS033 (1.5 mg/L T-Se) MSG003 (0.45 mg/L T-Se) <u>Ponds</u> MSP062	Sections C, H and Q (Drawings 12, 13 and 14) and Ballard Geology Map (Drawing 11)	Not a completed flow path.	None	Flow is primarily colluvial if present. Flowpath is intercepted by West Ballard Pit
	Open Mine Pit	MMP035, MMP039, MMP040, MMP037	No	27	---	---	Same as above	Not a completed flowpath.	None	There is no potential for direct discharge from pits to alluvium or colluvium (i.e., pits are a hydraulic sink below level of alluvium)
	Backfilled Mine Pit	None	No	---	---	---	---	Not a completed flowpath.	None	There are no backfilled mine pits at Ballard to the level of the alluvial or colluvial deposits in the area.
Intermediate – Dinwoody / Thaynes Formations	Waste Dump	Eastern Mine Area MWD084 MWD082	Yes	28	<u>Monitoring Wells</u> MMW018 (0.029 mg/L T-Se on top of Dinwoody Fm.)	None	Sections C, S and T (Drawings 12 and 15), and Ballard Geology Map (Drawing 11)	Possible impacts to Dinwoody Fm. from impacted alluvium has not been characterized.	Well installation may be needed once levels of selenium are better understood in the alluvial system.	Minimal direct contract between the waste rock deposits and the Dinwoody Fm. in this area.
		Western Mine Area MWD083 MWD080	No	31, 32, 33	None	None	Sections C, H, I, and R (Drawings 12, 13 and 14) and Ballard Geology Map (Drawing 11)	Not a completed flowpath	None	Dinwoody Formation not located in this area.

TABLE 3-3 DATA GAP MATRIX FOR THE BALLARD MINE										
Conceptual Flowpath	**Source Type**	**Location/ Potential Sources**	**Completed Flowpath**	**Agency Data Gap (item #)**	**Wells in Flowpath**	**Other Existing Data**	**Diagrams Illustrating Conceptual Model**	**Data Gap**	**Action to Address Data Gap**	**Note or Comment**
		Core Mine Area MWD093 MMP036	Possible but not significant	33	None	Springs MDS030 (0.55 mg/L T-Se) MDS031 (0.38 mg/L T-Se) MDS032 (0.40 mg/L T-Se) MDS033 (1.5 mg/L T-Se) MSG003 (0.45 mg/L T-Se)	C, H and Q (Drawings 12, 13 and 14) and Ballard Geology Map (Drawing 11)	General discharge is to interior mine areas; however, some flow to the drainage south of MMP035 is possible. Geology would direct this flow either to the alluvial system or Wells Formation.	None – alluvial and Wells Formation pathway will be addressed.	The potential loading to the external area of the mine is expected to be small and to other flow systems that will be evaluated.
	Open Mine Pit	MMP035 MMP036 MMP037 MMP039 MMP040	No	33	None	None	See Sections C, H and R (Drawings 12, 13 and 14) for examples.	Not a completed flowpath	None	Incomplete pathway because water from mine pits cannot discharge directly to the Dinwoody Fm. The one exception to this, MMP040, is located in the interior of the site and any impacted water will discharge to the west pit (MMP035).
	Backfilled Mine Pit	None	No	---	None	None	----	Not a completed flowpath, only minor areas of pit backfill.	None	
Regional – Wells Formation	Waste Dump	Eastern Mine Area MWD082 MWD084	Possible	35	None	None	See Geology Map (Drawing 11)	Potentiometric data; impacted groundwater flow in the alluvium could cross the trace of the Slug Valley Fault and infiltration into the underlying Wells Formation.	The direct-push program will help map the extent of selenium impacts in the alluvial system.	Groundwater flow in the Wells Fm. In this area is thought to be from the recharge area towards the site. If highly impacted groundwater is found on the east side of the Slug Valley Fault then this concept may need to be tested.
		Western Mine Area MWD080 MWD081 MWD083 MWD093	Yes	37	Monitoring Wells MM-15A (1.99 mg/L T-Se) MW-16A (0.049 mg/L T-Se) MMW017 (0.13 mg/L T-Se) indicate shallow impact Other Wells MAW008 (no data)	Ponds MSP062 (0.002 mg/L T-Se [2004]) Pond in Middle Ballard Mine Pit	Sections C, H, I and R (Drawings 12, 13 and 14)	Impacts to Wells Fm. are possible due to alluvium impacted from waste rock seepage. Groundwater quality and potentiometric data are needed.	Monitoring wells to the Wells Fm. are needed along the western perimeter of the mine area.	A geophysical evaluation of the thickness of the alluvial cover and position of an inferred range-bounding fault may be needed prior to well installation.
	Open Mine Pit	Eastern and Central Mine Area MMP037 MMP039 MMP040	No	35	None	None	See Section C(Drawings 12)	Flow projected to be east to west. Impacts to Wells Fm. east of the mine appear unlikely.	None at this time.	

TABLE 3-3 DATA GAP MATRIX FOR THE BALLARD MINE										
Conceptual Flowpath	**Source Type**	**Location/ Potential Sources**	**Completed Flowpath**	**Agency Data Gap (item #)**	**Wells in Flowpath**	**Other Existing Data**	**Diagrams Illustrating Conceptual Model**	**Data Gap**	**Action to Address Data Gap**	**Note or Comment**
		Western Mine Area MMP035 MMP036 MMP038	Yes	---	Monitoring Wells MMW020 (0.017 mg/L), MMW021 (0.047 mg/L), MMW006 (0.080 mg/L) Other Wells MAW008 (no data)	None	Sections C, H, I and R (Drawings 12, 13 and 14)	Impacts to Wells Fm. are possible due to impacts indicated in the mine area. Downgradient groundwater quality and potentiometric data are needed.	Monitoring wells to the Wells Fm. are needed along the western perimeter of the mine area. Flow is likely to the northwest and a monitoring well should be installed to address this flow direction.	Impacts are probably not a direct result of the mine pits, but the mine pit may act as a conduit to the Wells Formation for water seeping from waste rock. Flow will be directed by the bedding strike which is predominantly to the northwest.
	Backfilled Mine Pit	All	No	---	None	None	---	Not a completed flow path	None	Backfill mine pit are not a significant feature of the Ballard Mine area.
Structurally Controlled Flow	All	All	Yes	---	Monitoring Wells MMW020 (0.017 mg/L), MMW021 (0.047 mg/L), MMW006 (0.080 mg/L) Other Wells MAW008 (no data)	None	Illustrated on most Ballard sections.	It is also possible that some structures (e.g., along the south edge of the mine area) could result in impacted groundwater flow to the Wells Fm.	Installation of new wells on the western downgradient edge of the mine area.	Alternatively, the faults may act as flow barriers compartmentalizing the Wells Formation.

Notes:
Monitoring well data for wells installed in 2007 are preliminary data reported in Section 2 of this report. All other data are average data as reported in MWH (2007a).

TABLE 3-4
DATA GAP MATRIX FOR THE HENRY MINE

Conceptual Flowpath	Source Type	Location/ Potential Sources	Completed Flowpath	Agency Data Gap (item #)	Monitoring Wells in Flowpath	Other Existing Data	Diagrams Illustrating Conceptual Model	Data Gap	Action to Address Data Gap	Note or Comment
Local – Alluvial (Basalt)	Waste Dump	NE side of Henry Mine	Yes	18, 19	MMW019 (<0.001 mg/L), MMW010 (<0.001 mg/L), MMW014 (<0.001 mg/L)	Shallow basalt wells MMW003 & MMW004	Sections E, P, B, N & O (Drawings 16 – 19)	Extend of impacts to shallow alluvium not well understood	Direct-push boreholes	
		Valley fill portion of MWD087 (in Long Valley drainage)	Yes	--	None	None	Drawings 3 and 10	Alluvial groundwater has not been sampled below the toe of this dump.	Direct-push borehole	Configuration of this waste dump is very favorable for limiting infiltration.
		Alluvium NW of MWD085/MMP041	No	20	None	None	Drawings 3 and 10	None	None	Waste rock does not overlay an alluvial system in the area.
	Open Mine Pit	MMP041 and MMP044 (unbackfilled portions)	No	--	NA	None	Section P (Drawing 18)	None	None	There is not a direct flowpath between the open mine pits and the alluvial system.
	Backfilled Mine Pit	MMP041 through MMP044	Yes (one location)	16, 17	None	None	Sections B and E (Drawings 16 and 19)	Alluvial groundwater data from small drainage on south end of center Henry	Downgradient groundwater to be sampled in direct-push program	A flowpath may exist on the southern end of Center Henry as shown on Section E
Intermediate – Dinwoody / Thaynes Formations	Waste Dump	NE side of Henry Mine MWD086	Yes, Dinwoody Only	21, 22	MMW022 (0.017 mg/L)	None	Section B (Drawing 16)	Groundwater is slightly impacted as indicated by MMW022. A discharge location should be monitored if present. Flow may also occur to the northwest toward the Little Blackfoot River.	Spring survey to the northeast of MMW022 down a drainage cutting the Dinwoody Formation. In addition, a monitoring well should be installed in the Dinwoody Formation near the Little Blackfoot River.	The scale of Section B is appropriate to the amount and spacing of available geologic data – this section is more regional than the others.
	Open Mine Pit	NA	No	--	NA	None	NA	None	None	Dinwoody Formation is not exposed in the open pits.
	Backfilled Mine Pit	NA	No	--	NA	None	Sections B and E (Drawings 16 and 19)	None	None	Dinwoody Formation is not exposed in the open pits.
Regional – Wells Formation	Waste Dump	Valley fill portion of MWD087	Possibly	--	None	None	Drawing 10	If alluvium is impacted this could be a source to the Wells Formation	Sample alluvium and complete a water balance for the dump if an impact is seen.	Configuration of this waste dump is very favorable for limiting infiltration. A significant impact seems unlikely.
	Open Mine Pit	South & North Henry Pits (MMP041 and MMP044)	Yes	23	MMW023 (0.003 mg/L)	None	Section P (Drawing 18)	None	None	A significant impact is not apparent based on the data from MMW023, which was installed directly in the base of MMP041. Pathway does not appear significant.
	Backfilled Mine Pit	MMP041 through MMP044	Yes	23	MMW011 (<0.001 mg/L) (laterally placed along strike), MMW023 (0.003 mg/L)	None	Section B and N (Drawings 16 and 17)	None	None	Flow in Wells Formation should be direct toward Henry springs along the strike of the formation. MMW011 and MMW023 are ideally located for monitoring this flowpath.

TABLE 3-4 DATA GAP MATRIX FOR THE HENRY MINE										
Conceptual Flowpath	**Source Type**	**Location/ Potential Sources**	**Completed Flowpath**	**Agency Data Gap (item #)**	**Monitoring Wells in Flowpath**	**Other Existing Data**	**Diagrams Illustrating Conceptual Model**	**Data Gap**	**Action to Address Data Gap**	**Note or Comment**
Structurally Controlled Flow	All	Between MWD085 & MMP043 along Little Blackfoot River	No	24	MMW004 (<0.001 mg/L), MMW011 (<0.001 mg/L), MMW019 (<0.001 mg/L)	None	NA	Potential flowpath not characterized. However, there is not a direct apparent source.	None	This is a secondary flowpath as there is not direct contact with waste.
		South of Henry Mine and MMP044	No	25	None	None	NA	Fault not characterized; however conceptually it is not a flowpath.	None	Flow in the Wells Formation should be to the northwest and the thrust fault is most likely a flow barrier.
		Primarily backfilled mine pits as a potential source to the regional flow system	NA	Comments on draft of this document	Water level data from MMW011 and MMW023 will be key in assessing the flowpath	Data being collected in 2008	NA	Cross cutting structures may divert flow along the strike of the Wells Formation and wells located on the north end of the mine may not be hydraulically connected to the south end.	Monitoring of water level responses across the probable structure where the Little Blackfoot River crosses the mine.	An indication of compartmentalization could result in the need for an additional Wells Fm. well in the southern portion of the mine.
Notes: Monitoring well data for wells installed in 2007 are preliminary data reported in Section 2 of this report. All other data are average data as reported in MWH (2007a).										

TABLE 3-5
DATA GAP MATRIX FOR THE ENOCH VALLEY MINE

Conceptual Flowpath	Source Type	Location/ Potential Sources	Completed Flowpath	Agency Data Gap (item #)	Wells in Flowpath	Other Existing Data	Diagrams Illustrating Conceptual Model	Data Gap	Action to Address Data Gap	Note or Comment
Local – Alluvial	Waste Dump	Southern Mine Area - MWD092 (Stormwater ponds MSP017 through MSP021)	Yes	11	Monitoring Wells MMW007 (0.002 mg/L T-Se) MMW008 (<0.001 mg/L T-Se) MMW013 (<0.001 mg/L T-Se)	Stormwater ponds and dump seeps with elevated selenium (e.g., MSD026 and MSP017)	Sections D, J and K (Drawings 21 and 22)	Monitoring wells are installed at the alluvium/Dinwoody Fm. contact. Potential seasonal and shallower alluvial flow needs to be evaluated. Also need greater spatial coverage.	Direct-push sampling will be implemented per MWH (2007b).	Data to date suggest the deeper alluvial system is not impacted.
		Northern Mine Area - MWD091	Yes	12	Monitoring Wells MMW012 (dry) Other Wells MAW001, MAW002, MAW003, MDW001, and MDW002 all had T-Se <0.001 but may not draw exclusively from alluvium.	Springs MST059, 60 & 61 (dry)	Section L (Drawing 23)	Alluvial groundwater has not been located or sampled.	Direct-push sampling will be implemented per MWH (2007b).	Direct-push program will address three potential drainages with associated alluvium in this area.
	Open Mine Pit	None	No	--	---	---	Same as above.	None	None	There is no potential for discharge from pits to alluvium (i.e., pits are a hydraulic sink below level of alluvium)
	Backfilled Mine Pit	None	No	--	---	---	Same as above	None	None	There is no potential for discharge from pits to alluvium (i.e., pits are a hydraulic sink below level of alluvium)
Intermediate – Dinwoody / Thaynes Formations	Waste Dump	Southern Mine Area, W of MWD092, near MDS025	Yes	6, 8	Monitoring Wells MMW013 (<0.001 mg/L T-Se)	None directly related to Dinwoody Fm.	Section K (Drawing 22)	Shallow Dinwoody Fm. not impacted, but deeper flowpath from beneath the interior of MWD092 has not been evaluated.	Possible well location nested with MMW013.	
		Central Mine Area near MPW020 (central portion of MWD091 pit backfill)	No	6	None	---	Section A (Drawing 20)	None	None	No or very minor source to Dinwoody Fm. at this location. At this time it is not considered a completed flowpath.
		Northern Mine Area west of MWD091 near MMW012	Yes	7	Monitoring Wells MMW012, but in alluvium Other Wells MAW001, MAW002, MAW003, MDW001, and MDW002 all had T-Se <0.001. May not draw in part from the Dinwoody or Thaynes.	Springs MST059, MST060 and MST061 but flow from these locations has never been identified or sampled.	Sections L and M (Drawing 23 and 24)	Potential Dinwoody Fm. flowpath has not been tested in this area.	Possible well location nested with MMW012. May be contingent on alluvial impacts.	Size of potential source and source configuration suggests that impacts would be less likely than on the southern end of the Enoch Valley Mine.

TABLE 3-5 DATA GAP MATRIX FOR THE ENOCH VALLEY MINE										
Conceptual Flowpath	**Source Type**	**Location/ Potential Sources**	**Completed Flowpath**	**Agency Data Gap (item #)**	**Wells in Flowpath**	**Other Existing Data**	**Diagrams Illustrating Conceptual Model**	**Data Gap**	**Action to Address Data Gap**	**Note or Comment**
		Near MMW007	Yes	9	Monitoring Wells MMW007 (0.002 mg/L) and MMW008 (<0.001 mg/L)	None directly related to Dinwoody Fm.	Sections D and J (Drawing 21)	Shallow Dinwoody Fm. not impacted, but deeper flowpath from beneath the interior of MWD092 has not been evaluated.	Possible well location nested with MMW007.	
	Open Mine Pit	Center mine area MMP045	No	--	---	---	Section A (Drawing 20)	None	None	At Enoch Valley the Dinwoody Fm. is not exposed in the mine pits such that it completes a flowpath for this type of facility.
	Backfilled Mine Pit	Northern and southern mine area – pits MMP045, with MWD091 backfill.	No	--	---	---	Sections M and K (Drawings 22 and 24)	None	None	At Enoch Valley the Dinwoody Fm. is not exposed in the mine pits such that it completes a flowpath for this type of facility.
Regional – Wells Formation	Waste Dump	None	No	--	None	None	Sections A, K and M (Drawing 20, 22 and 24)	None	None	Waste dumps are not a direct source to the Wells Fm. All outcrops of the Wells Fm. are to the east.
	Open Mine Pit	MMP045	Yes	13	Other Well MPW020 screened in Rex Chert down-dip of mine pit contains no detectable T-Se	None	Section A (Drawing 20)	Wells Formation flow system down-dip of open pit has not been evaluated.	None	Monitor well installation technically challenging in this area. Addressing this data gap is deferred pending results from other Wells Fm. studies.
	Backfilled Mine Pit	MMP045	Yes	13	Monitoring Well MMW009 (0.001 mg/L T-Se) Other Wells potentially MPW006 and MAW005 (both <0.001 mg/L T-Se)	None	Sections K and M (Drawings 22 and 24)	MMW009 is in place in the northern portion of the mine area. The center and southern portions are not covered. However, due to the steep dip of the Wells Formation, well installation in the central area will be difficult.	Installation of a new Wells Formation well on the southern end of the backfilled Enoch Valley mine pit.	Groundwater flow to the northwest or southeast in the Wells Fm. is more likely to reach receptors and can be investigated without excessive well drilling.
Structurally Controlled Flow	Waste Dump and associated backfilled mine pit.	MWD091, MMP045	Unknown	14	None	None	None	An evaluation is needed to assess if the structure provides an enhanced groundwater pathway.	Field evaluation of the flexure area.	The mapping does not suggest a structure with large displacement and potentially large open faults.

Notes:
Monitoring well data for wells installed in 2007 are preliminary data reported in Section 2 of this report. All other data are average data as reported in MWH (2007a).

4.0 PRELIMINARY IDENTIFICATION OF 2008 FIELD ACTIVITIES

The review of the conceptual models indicates some data gaps as summarized in Tables 3-3 through 3-5. Activities to address these data gaps are generally discussed herein. Specific locations, methods and procedures will be presented in a separate technical memorandum for the 2008 field program. However, a substantial component of the 2008 field program will be the Direct-Push Sampling Program, and this work plan has already been submitted and reviewed by the Agencies, as described below.

4.1 DIRECT-PUSH SAMPLING PROGRAM

A significant component of the groundwater investigation to be conducted in 2008 will be the Direct-Push Groundwater Sampling Investigation (MWH, 2007b). This investigation has the potential for providing a large amount of data related to the potential impacts to the shallow alluvial system and will address many data gaps associated with that flow system. For several reasons, the alluvial system may be the most important to evaluate. Most notably, exposure pathways to the alluvial system are the most direct.

The draft Direct-Push Groundwater Sampling Work Plan was originally to be implemented in the fall of 2007. However, the drilling program results suggested that water levels in the alluvial system were depressed, and if implemented in the fall, the direct-push program may not be as successful as hoped. Therefore, the program was delayed until the spring of 2008 with the objective of sampling when the water table will be elevated, and thereby, increasing the probability of successfully obtaining samples.

The draft Direct-Push Groundwater Sampling Work Plan was submitted to the Agencies in November 2007 (MWH, 2007a), and the Agencies provided comments in December 2007. The Agencies requested some additional areas be sampled and suggested some procedures for hydraulic testing and temporary well installation. P4 responded to these comments and submitted a revised work plan on January 18, 2008. The Agencies were reviewing the revised work plan at the time of this submittal.

Generally, the direct-push program will evaluate each of the larger alluvial systems at each mine with multiple direct-push sampling locations. The direct-push program will provide a valuable screening-level evaluation of the alluvial flow system. Analysis of the data will help address data gaps associated with the alluvial systems and locate longer term monitoring points in strategic locations, if needed.

4.1.1 Contingency Plan

It is possible that the direct-push sampling will not be successful in all areas either because of a depth to groundwater greater than the method can address, or because sediments that might yield too little groundwater. In a situation where bedrock is encountered without locating groundwater, there are no further actions and the shallow alluvial pathway will be considered absent at such a location.

In other cases where groundwater sampling was not successful due to a limitation of the direct-push method, a conventionally installed shallow monitoring well will be considered. Such wells would be installed with either hollow-stem auger or sonic drilling methods. The demand for logging such an installation may be reduced where direct-push cores have already been advanced, but where drilling is required below the depth of the direct-push boreholes, continuous coring would be done. Details, other than location and numbers, pertaining to the installation of shallow alluvial monitoring wells are included in the Phase IIb Monitoring Well Installation Technical Memorandum; however, it is uncertain at this time if any conventional shallow alluvial monitoring wells will be needed.

It is not possible to provide detailed responses to various scenarios that may occur in the individual investigation areas. This is because there are many possibilities for partial success that would provide sufficient data to address the data gap, or provide data for locating strategically-placed conventional shallow monitoring wells to complete the investigation. A determination of completeness may also require assessing the analytical results.

The Agencies will be informed on a weekly basis of the status of the direct-push program, and agency personnel are, of course, welcome to observe the program being implemented in the field. As each area is completed, the percent of completion of the plan will be reported along with recommendations for addressing any data gap that remains due to incomplete data collection. These recommendations may range from no further action to additional conventional well installation depending upon the area and results obtained.

The direct-push program will be initiated in the spring of 2008, and depending upon the scope, any conventional shallow drilling program should also be completed in 2008. This assumes that that P4 Production and the Agencies agree to the requirement and methods to address any remaining data gaps in a timely manner.

4.2 HYDROGEOLOGIC TESTING

As the investigation moves into the comprehensive data analysis phase, analysis of contaminant transport will require certain hydrologeologic parameters. For example, the evaluation of the infiltration of dump seepage to the underlying alluvium will require hydraulic conductivity data. Hydraulic gradients and flow directions will also need to be estimated. To provide the data needed for these evaluations the following testing and measurements will need to be completed:

- Finalize surveying of the measuring point (top of casing) and ground surface elevations at all monitoring wells and piezometers, and relevant seeps and springs;
- Hydraulic testing of monitoring wells in key units and areas; and
- Installation of water level data loggers in select monitoring wells.

Due to the fall completion of the monitoring well installation program and other surveying requirements, the surveying of the wells installed in 2007 was not completed before weather conditions restricted access. For most wells not surveyed, hand-held GPS data are available, but this data has relatively poor accuracy. Surveyed elevations will be reported to at least tens-of-a-foot (0.0) and where possible to hundreds-of-a-foot.

Hydraulic conductivities for the various units will need to be estimated for any flow velocity and contaminate transport calculations   Field measured hydraulic conductivities are important for these analyses. Monitoring wells less than 150 feet deep will have the hydraulic conductivity of the screened formation tested by using the “slug test” procedure. This procedure introduces (instantaneously as practicable) a known volume to the well and measures the response of the water-bearing formation. Either water can be introduced or a solid slug on a rope or cable. With a solid, the response to insertion and withdrawal can be measured. For selected deeper wells, the feasibility of single well pneumatic slug tests will be evaluated.

4.3 WELL INSTALLATION

A program of focused monitoring well installation will have to be implemented in 2008 to supplement the data collected in 2007 and help address remaining data gaps. As mentioned previously, the final number and position of new monitoring wells will be provided in a subsequent groundwater investigation technical memorandum. However, the flow paths and areas where installation is being evaluated are summarized below.

4.3.1 Ballard Mine Area

Selenium impacts to the shallow alluvial system have been demonstrated at the Ballard Mine. This flowpath will largely be investigated with the direct-push program in the spring of 2008. However, some permanent monitoring well installations will likely be recommended. This will either be direct-push installations using pre-packed screens or conventional well installations. The recommendations for these monitoring locations will be presented in the Direct-Push Groundwater Sampling Work Plan (MWH, 2007b), revised to address Agencies comments, or in the pending groundwater investigation technical memorandum for 2008.

A potential impact to the bedrock system east of the mine should be assessed. In the case of the eastern mine area, the Dinwoody Formation is the potential flow system that may be impacted. The configuration of the eastern portion of the mine is relatively hydrogeologically restrictive, and a single well may be useful in assessing this potential impact. However, some flexibility should be provided to incorporate the results of the direct-push alluvial characterization.   The Dinwoody Formation monitoring well should be located in an area with greatest apparent impact to the alluvial system to test the pathway. A nested alluvial-Dinwoody well may be needed to help evaluate the vertical hydraulic gradient depending upon the location (e.g., if alluvial data are not already available).

Investigation of the Wells Formation along the western perimeter of the mine is needed for a similar reason as on the eastern side. There are two potential sources that may impact Wells Formation groundwater in this area. These sources include impacted alluvial groundwater and infiltration to the Wells Formation from mine pits. At least two monitoring wells will be needed to assess this flowpath; however, either exploratory drilling or a geophysical survey will be needed to help confirm the presence and depth of the Wells Formation beneath the alluvium.

4.3.2 Henry Mine Area

One well is recommended in the Henry Mine area. This well would be used to assess the potential flowpath from the MMW022 area toward the Little Blackfoot River and would be installed in the Dinwoody Formation near the river. At this time, no other well installation is recommended in the Henry Mine area. However, if impacts are indicated by the direct-push groundwater sampling program, additional wells may be installed. Confirmation of the flow direction in the Wells Formation is also needed. If the conceptual flow direction toward the spring near Henry is confirmed, then the current well configuration is well suited for monitoring this flowpath.

4.3.3 Enoch Valley Mine Area

Ponds and seeps directly associated with the mine wastes at the Enoch Valley Mine suggest that impacts to the groundwater system are possible. However, wells installed to date have not demonstrated any significantly elevated total selenium concentration (e.g., one-tenth of the MCL). However, data gaps remain. Most significantly, due to the time of year when the 2007 hydrogeologic investigation was implemented, the alluvial groundwater table appears to have been depressed. As a result, the shallow alluvial system has not been characterized. The direct-push groundwater sampling investigation will help address this data gap.

Within the Dinwoody Formation three monitoring wells have been installed in the uppermost decomposing surface that is in contact with the alluvium. Measured selenium concentrations in groundwater from this horizon are low (0.002 mg/L and less). In addition, this system is more directly a continuation of the alluvial system. While these data suggest that impacts to the deeper flowpaths in the Dinwoody are also relatively un-impacted, no data are available to support this supposition. A deeper flowpath with a potential source area near the interior of the adjacent waste rock dump is possible on the south end of the Enoch Valley Mine. A nested well with MMW013 could be used to help evaluated this flowpath. A similar well located near MMW007 could also be used to evaluate a southeasterly flow direction.

In the Wells Formation regional flow system monitoring well MMW009 is in the flowpath ideally located to monitor potential downdip flow from a backfilled mine pit and also flow along strike from more southerly portions of the mine. A new Wells Formation monitoring well will be installed on the southern end of the backfilled Enoch Valley mine pit. This well will address a possible southeasterly flow direction in the Wells Formation along the strike of that unit. Positioning of the well will be based on geologic data obtained from the geologic model of Enoch Valley. A small amount of external waste rock may be located at the selected site, requiring an isolation casing to be advanced to the depth of bedrock. Currently the Agrium production well MPW006 is not used, and the new well will be located roughly 2,000 feet away from the production well. Therefore, MPW006 is not expected to have a hydraulic impact on the new well. However, the new monitoring well will be equipped with a water level logger, and should MPW006 go back into use the logger data can be used to identify any effect.

4.4 WATER QUALITY SAMPLING AND MONITORING

Groundwater sampling will be conducted for all the monitoring wells in the spring and fall of 2008. This sampling plan will be presented in the 2008 Phase IIb Monitoring Well Installation Technical Memorandum. Water level responses to recharge events provide key information on the hydrogeologic character of the associated hydrogeologic units. To facilitate this data collection and evaluation, data loggers will be installed in several wells. Details will be presented in the pending technical memorandum describing the 2008 field activities.

5.0 SUMMARY OF KEY OBSERVATIONS

This report has presented data collected in 2006 and 2007, and updated and expanded conceptual models for the Ballard, Henry and Enoch Valley Mine sites. The validation and evaluation of the 2006 and 2007 data are not complete at this time, and the data presented should be considered preliminary. However, the data are sufficient for use in updating the conceptual models and helping to guide the next phase of investigation. In general, this is an ongoing process that will undergo more iteration until presentation of the final site investigation report.

During review of the data collected to date and during the process of updating the conceptual model there have been a number of important observations and hypotheses developed. These observations and hypotheses are summarized as follows.

- Key, worst case, groundwater flow pathways were characterized in 2007 through the installation of 16 monitoring wells. These pathways include the local, intermediate, and regional flow systems typical for the southeastern Idaho phosphate mining area.

- Generally, the Enoch Valley and Henry mine areas were found to be less impacted than the Ballard Mine area. A significant reason for this is likely the higher level of reclamation completed at the two more modern mines. Age, as it relates to travel time and extent of weathering of the waste rock, may also be a factor, but in many cases at Henry and Enoch Valley the groundwater has been evaluated very close to potential sources without observed impacts to the groundwater.

- Where impacts have been observed there is a pattern of lower levels of contamination with increasing depth. Groundwater springs discharging from the shallowest portion of the alluvial system, when contaminated, display generally higher levels of selenium than do deeper contaminated portions of the alluvial system, which in turn is less impacted than the bedrock flow systems. This can be observed in several areas like on the east side of the Ballard Mine where MMW018 (0.029 mg/L total Se) in the deeper alluvium has lower selenium concentrations than springs located in the same area and further downgradient from the source (e.g., MSG006, up to 0.15 mg/L). It is also notable at Enoch Valley where dump seep MDS026 (0.068 - 0.019 mg/L total Se) is located adjacent to alluvial monitoring well MMW007 (0.002 mg/L total Se).

- None of the new monitoring wells at Enoch Valley or Henry mine areas exceed the groundwater quality standard of 0.05 mg/L for total selenium, and seven of the new wells do not have detectable selenium.

- Data provide no indication that there is a significant impact to the regional groundwater flow system in the Henry or Enoch Valley mine areas. At the Henry Mine flow in the regional system is likely to the northwest and the existing wells are well positioned for monitoring this system; however, survey data are needed to confirm the flow direction. At the Enoch Valley Mine groundwater flow in the regional system is also likely to the northwest and MMW009 is well positioned to monitor this flow system. However, data are proposed to be collected on the southeast end of the mine in 2008 to confirm the flow system gradient.

- Impacts appear to be confined to a few springs discharging from the uppermost portion of the local alluvial system at the Henry and Enoch Valley mines. This will be further evaluated in 2008 through the direct-push program. The intermediate flow system in the Dinwoody Formation will also be further evaluated in 2008.

- Five new wells were installed in the Ballard Mine area with detected total selenium in all five wells with two wells exceeding the groundwater quality standard.

- Both the local alluvial and regional Wells Formation flow systems have elevated selenium concentrations present in groundwater at the Ballard Mine. The Dinwoody Formation is present in the Ballard Mine area, but groundwater flow in the formation is best characterized as a local flow system.

- Collection of groundwater data from the uppermost decomposing portion of the Dinwoody Formation east of the Ballard Mine in MMW018 suggests a vertical concentration gradient in the alluvial system consistent with a surficial source of contamination – i.e., a waste rock dump.

- Groundwater flow in the Wells Formation is conceptualized as being to the northwest in the regional flow system based on the structural grain of the geology in the Ballard Mine area. However, the faulting in the mine area appears to have compartmentalized the groundwater system limiting flow.

As a result of reviewing and updating the conceptual models with new information gathered in 2006 and 2007 several key data gaps have been revealed. The following Table 5-1 summarizes these key data gaps, as data needs, and the associated potential activities for the 2008 field season. As presented in this report, and consistent with the original conceptual model, the alluvial system is the groundwater flow system most impacted by the mining operations. In addition, the alluvial system represents the most direct contaminant transport route to potential receptors. Because of this, the largest effort in 2008 will be focused on further characterizing the alluvial system.

TABLE 5-1 SUMMARY OF DATA NEEDS AND PROBABLE DATA COLLECTION ACTIVITIES		
Location	**Data Need**	**Data Collection Activity**
All Three Mines	In the bordering alluvial systems there is a need for increased horizontal and vertical spatial coverage. For Henry and Enoch Valley this is largely to confirm the absence of significant impact, while at Ballard the extent of contamination needs to be confirmed.	Direct-push groundwater sampling and alluvial material logging (MWH, 2007b).
Ballard Mine	Possible impacts to the Dinwoody Fm. flow system from impacted alluvium need to be tested.	Installation of a monitoring well into the Dinwoody Formation east of the mine once the impacts in the alluvial system are better defined (i.e., the well will be installed in an area with elevated selenium in the alluvial system).
Ballard Mine	Possible impacts to the Wells Formation from impacted alluvium west of the mine need to be evaluated.	Two monitoring wells to be installed into the Wells Formation below the alluvial system. At least one will be installed in an area of known impact. The second will be located downgradient in the direction of probable regional groundwater flow (see below).
Ballard Mine	Wells within the mine area have elevated selenium and data needs to be collected in the downgradient area to help evaluate extent of contamination.	A monitoring well will be installed in the most probable downgradient location from the mine in the Wells Formation regional flow system. This monitoring well will also serve as one of the two wells discussed above.
Ballard Mine	Flow in the Wells Formation may be limited by faulting that generated compartmentalization.	Responses to groundwater recharge events will be monitored with data loggers in wells MMW020, MMW021 and MMW006 and any new Wells Formation wells installed.
Henry Mine	An impact to the intermediate flow system associated with the Dinwoody Formation has been indicated, data is needed to further characterize this system. Flow is possible to the northeast and northwest.	A monitoring well will be installed in the Dinwoody Formation near the Little Blackfoot River to assess the potential northwest flow direction, and a spring survey will be conducted along Dinwoody outcropping to the northeast.
Enoch Valley Mine	Waste rock has been deposited on the Dinwoody Formation in the southern portion of the mine and a pathway may be present where deeper Dinwoody beds could be impacted.	Co-locating deeper Dinwoody Formation monitoring wells with MMW007 and MMW013. The wells would be screened below the weathered portion of the unit.
Enoch Valley Mine	A smaller area of waste rock has been placed on the Dinwoody Formation in the northern portion of the mine. If alluvial impacts are demonstrated then the underlying Dinwoody Fm. should be evaluated.	If alluvial impacts are found in MMW012 or during the Direct-Push program, a Dinwoody Formation monitoring well near MMW012 may be needed.
Enoch Valley Mine	Groundwater flow could be to the southeast along the strike of bedding in the Wells Formation and groundwater quality and potentiometric data are needed to assess this pathway.	Installation of a monitoring well into the Wells Formation in the MMW008/MPW006 area. MPW006 will be evaluated further to determine if it can be suitably modified to address the data need.
Enoch Valley Mine	A structure is present in the northern half of the mine area that results in a change in the bedding strike and dip. The character of this structure needs to be better understood to assess its potential effect on groundwater flow.	Further data and field research will be conducted.

6.0 REFERENCES

Alpers, C.N., and Blowes, D.W., 1994. *Environmental Geochemistry of Sulfide Oxidation.* ACS Symposium Series 550, American Chemical Society, Washington D.C., 681 p.

Balistrieri L.S. and Chao, T.T, 1990. *Adsorption of Selenium by Amorphous Iron Oxy-Hydroxide and Manganese Dioxide.* Geochimica et Cosmochimica Acta, vol. 54, p.739-751.

Bar-Yosef, B. and Meek, D., 1987. *Selenium Adsorption by Kaolinite and Montmorillonite.* Soil Science, vol. 144, No. 1 July 1987, p. 11-19.

Brooks, T.D., 1982. *Hydrology of the Proposed North Henry Mine, Southeastern Idaho.* Thesis, University of Idaho, May 1982.

BLM (U.S. Bureau of Land Management), 1999. *Draft Environmental Impact Statement, Dry Valley Mine-South Extension Project.*

Connor, J.J., and Shacklette, H.T., 1975. *Background Geochemistry of Some Rocks, Soils, Plants, and Vegetables in the Conterminous United States.* U.S. Geological Survey Professional Paper 574-F, 168 p.

Cowan, C.E., Zachara, J.M., and Resch, C.T., *Solution ion effects on the surface exchange of selenite on calcite.* Geochemica et Cosmochimica Acta, vol. 58, pp. 2223-2234.

Desborough, G.A., DeWitt, E., Jones, J., Meier, A., and Meeker, G., 1999. *Preliminary Mineralogical and Chemical Studies Related to The Potential Mobility of Selenium and Associated Elements in Phosphoria Formation Strata, Southeastern Idaho.* USGS

Desborough, G.A., and Poole, F.G., *Metal concentrations in some marine black shales of the United States*. in Cameron Volume on Unconventional Mineral Deposits, W.C. Shanks, ed., Society of Mining Engineers, Littleton, Colorado, pp. 99 – 110.

Freeze, R.A. and Cherry, J.A., 1979. *Groundwater.* Prentice-Hall, Inc., Englewood Cliffs, New Jersey. 604 p.

Grauch, R.I., Tysdal, R.G., Johnson, E.A., Herring J.R., and Desborough, G.A., 2001. *Stratigraphic Section and Selected Semiquantitative Chemcistry Meade Peak Phosphatic Shale Member of Permian Phosphoria Formation, Central Part of Rasmussen Ridge, Caribou County, Idaho.* United States Geological Survey Open-File Report 99-20-E, USGS, Denver, CO, 1 Plate

Gulbrandsen, R. 1960. *Petrology of the Meade Peak Phosphatic Shale Member of the Phosphoria Formation at Coal Canyon, Wyoming.* United States Geological Survey Bulletin 1111-C p. 71-146.

Hayes , K.F., Roe, A.L., Brown, G.E., Hodgson, K.O., and Parks, G.A., 1987. *In-Situ X-Ray Adsorption Study of Surface Complexes: Selenium Oxyanions on Alpha-FeOOH.* Science, Vol. 238, p. 783-786.

Hem, 1989, *Study and Interpretation of the Chemical Characteristics of Natural Water.* United States Geological Survey Water-Supply Paper 2254.

Herring, J. R., Desborough, G.A., Wilson, S.A., Tysdal, R.G., Grauch, R.I., and Gunter, M.E., 1999. *Chemical Composition of Weathered and Unweathered Strata of the Meade Peak Phosphatic Shale Member of the Permian Phosphoria Formation.* United States Geological Survey Open-File Report 99-147-A, USGS, Denver, CO

Herring, J. R., Grauch, R.I., Siems, D.F., Tysdal, R.G., Johnson, E.A., Zielinski, R.A., Desborough, G.A., Knudsen, A., and Gunter, M.E., 2001. *Chemical Composition of Strata of the Meade Peak Phosphatic Shale Member of the Permian Phosphoria Formation; Channel-Composited and Individual Rock Samples of Measured Section J and Their Relationship to Measured Sections A and B, Central Part of Rasmussen Ridge, Caribou County, Idaho*, United States Geological Survey Open-File Report 01-195, USGS, Denver, CO., 68 p.

Herring, J.R., 2004. Chapter 12. *Lithogeochemistry of the Meade Peak Phosphatic Shale Member of the Phosphoria Formation, Southeast Idaho.* in Handbook of Exploration and Environmental Geochemistry, Volume 8 - Life Cycle of the Phosphoria Formation: From Deposition to Post-Mining Environment, J.R. Hein editor, Elseveir B.V., Amsterdam, pp. 321 – 366.

Herring, J.R., 2004. Chapter 13. *Rock Leachate Geochemistry of the Meade Peak Phosphatic Shale Member of the Phosphoria Formation, Southeast Idaho.* in Handbook of Exploration and Environmental Geochemistry, Volume 8 - Life Cycle of the Phosphoria Formation: From Deposition to Post-Mining Environment, J.R. Hein editor, Elseveir B.V., Amsterdam, pp. 367 – 397.

Hockin S. and Gadd, G. 2003. *Linked Redox Precipitation of Sulfur and Selenium under Anaerobic Conditions by Sulfate-Reducing Bacterial Biofilms.* Applied and Environmental Microbiology. v. 69, p. 7063-7072.

Hovland, R.D., 1981. *Geology of the Northwest Part of the Lower Valley Quadrangle Caribou County, Idaho.* San Jose State University Masters Thesis, 108 p.

Idaho Department of Environmental Quality (IDEQ), 2007a. *Agency/Tribal Direction For Groundwater Characterization And Data Gap Analysis at P4 Production, LLC, Enoch Valley, Henry And Ballard Mine Sites, Idaho.*

IDEQ, 2007b. *IDEQ Response to P4 Production, LLC Response to Agency/Tribal Direction for Groundwater Characterization and Data Gap Analysis at P4 Production, LLC Enoch Valley, Henry and Ballard Mine Sites, Idaho.* Letter from Mike Rowe to Robert Geddes, 11 July 2007.

Li, M., 2000. *Unsaturated flow and solute transport observations in large waste rock columns.* ICARD 2000, Proceedings from the Fifth International Conference on Acid Rock Drainage, Society for Mining, Metallurgy, and Exploration, Inc. (SME), Littleton, Colorado, pp. 247-256.

Mansfield, G.R., 1927. *Geography, Geology, and Mineral Resources of Part of Southwestern Idaho;* with Descriptions of Carboniferous and Triassic Fossils, by G.H. Dirty. U.S. Geological Survey, Professional Paper 152. 453 p.

Masscheleyn, P.H., Delaune, R.D. 1990, and Patrick, W.H. 1990. *Transformations of Selenium as Affected by Sediment Oxidation-Reduction Potential and pH.* Environmental Science and Technology, v. 24, p. 91-96.

Maxim Technologies, 2002. *North Rasmussen Ridge Mine Expansion Final Environmental Geochemistry Study.* Prepared for Agrium Conda Phosphate Operations.

McLean, J.E., and Beldsoe, B.E., 1992. *Behavior of Metals in Soils.* USEPA Groundwater Issue, EPA/540/S-92/018, 25 p.

Mayo, A.L., 1982. *Ground Water Flow Patterns in the Meade Thrust Allochton, Idaho-Wyoming Thrust Belt, Southeastern Idaho.* PhD Dissertation, University of Idaho, May 1982.

Mohammad, O.M.J., 1976. *Evaluation of the Present and Potential Impacts of Open Pit Phosphate Mining on Groundwater Resource System in Southeastern Idaho Phosphate Field.* PhD Dissertation, University of Idaho, December 1976.

Molson, J.W., Fala, O., Aubertin, M., Bussiere, B., 2005. *Numerical simulations of pyrite oxidation and acid mine drainage in unsaturated waste rock piles.* Journal of Contaminant Hydrology, vol. 78, pp. 343-371.

MWH, 2004. *P4 Production Southeast Idaho Mine-Specific Selenium Program 2004 Comprehensive Site Investigation Final Work Plans for Ballard, Henry and Enoch Valley Mines.* March 2004.

MWH, 2005. *Final 2005 Phase II Supplemental SI Groundwater Work Plan* (Phase II Groundwater Work Plan). April 2005.

MWH, 2007a. *Monitoring Well Installation Technical Memorandum for Final 2005 Phase II Supplemental SI Groundwater Work Plan.* Prepared by MWH for P4 Production, Southeast Idaho Mine-Specific Selenium Program, February 2007.

MWH, 2007b. *Draft- Direct-Push Groundwater Sampling Work Plan, Ballard, Henry, and Enoch Valley Mines.* Prepared by MWH for P4 Production, Southeast Idaho Mine-Specific Selenium Program, November 2007.

Neal, R.H., 1990. *Selenium.* in Heavy Metals in Soils, B.J. Alloway, ed., John Wiley and Sons, Inc., New York, pp. 237 – 260.

Nicholson, R.V., Gillham, R.W., and Reardon, E.J., 1990. *Pyrite oxidation in carbonate-buffered solution: 2. Rate control by oxide coatings.* Geochemica et Cosmochimica Acta, vol. 54, pp. 395-402.

Oberlindacher, P., Hovland, R.D., and Miller, S.T., 1982. *Geologic Map of the Aspen Range, Grays Range-Wooley Range, Schmid Ridge, and Webster Range-Dry Ridge known Phosphate Leasing Areas, Southeastern Idaho.* U.S. Geological Survey Open File Report 82-30.

Perkins, R.B., and Foster, A.L., 2004. *Mineral affinities and distribution of selenium and other trace elements in black shale and phosphorite of the Phosphoria Fromation.* Handbook of Exploration and Environmental Geochemistry, Volume 8 - Life Cycle of the Phosphoria Formation: From Deposition to Post-Mining Environment, J.R. Hein editor, Elseveir B.V., Amsterdam, pp. 251 – 295.

Pickering I., Brown, G., and Tokunaga, T., 1995. *Quantitative Speciation of Selenium in Soils Using X-Ray Absorption Spectroscopy.* Environmental Science and Technology, vol 29, No. 9, p. 2456-2459.

Rajan, S., 1979. *Adsorption of Selenite, Phosphate, and Sulphate on Hydrous Alumina.* Journal of Soil Science, No. 30, p. 709-718.

Ralston, D.R., Mohammad, O.M.J., Robinette, M.J., and Edwards, T.K., 1977. *Solutions to Water Resource Problems Associated with Open Pit Mining in the Phosphate Area of Southeastern Idaho.* Completion Report for Groundwater Study Contract No 50-897. U.S. Department of Agriculture, Forest Service, 125 p.

Ralston, D.R., Wai, C.M., Brooks, T.D., Cannon M.R., Corbet T.F., Singh, H. Winter, G.V., 1980. *Interaction of Mining and Water Resource Systems in the Southeastern Idaho Phosphate Fields.* Idaho Water and Energy Research Institute, University of Idaho, Moscow, Idaho. February 1980.

Ralston, D.R., Mayo, A.L., Arrigo, J.L., Baglio, J.V., Coleman, L.M., Hubbell, J.M., and Souder, K., 1983. *Thermal Ground Water Flow Systems in the Thrust Zone in Southeastern Idaho.* Submitted to Idaho Department of Water Resources. Idaho Water and Energy Research Institute, University of Idaho, Moscow, Idaho. May 1983.

Schroeder, P. R., Dozier, T.S., Zappi, P. A., McEnroe, B. M., Sjostrom, J. W., and Peyton, R. L., 1994. *The Hydrologic Evaluation of Landfill Performance (HELP) Model: Engineering Documentation for Version 3.* EPA/600/R-94/168b, September 1994, U.S. Environmental Protection Agency Office of Research and Development, Washington, DC.

Seed, K., Cave, M., Carter, J., and Parker, A., 2000. *Determination of Soil Selenium Speciation Using a New Extraction Methodology and Chemometric Data Analysis.* Journal of Conference Abstracts, v. 5(2) p. 902-903.

Stolz, J.F., Basu, P., and Oremland, R.S., 2002. *Microbial transformation of elements: the case of arsenic and selenium.* International Microbiology, v.5, p. 201-207.

Whetstone Associates, Inc., 2006. *Baseline Study Plan for Geochemical Characterization Blackfoot Bridge Mine EIS Project.* Prepared for U.S. Department of Interior Bureau of Land Management, on behalf of Monsanto Corporation / P4 Production Blackfoot Bridge Mine, March 2006.

Winter, G.V., 1980. *Groundwater Flow Systems of the Phosphate Sequence, Caribou County, Idaho.* M.S. Thesis, University of Idaho.

Zehr, J.P., and Oremland, R.S., 1987. *Reduction of selenate to selenide by sulfate-respiring bacteria: experiments with cell suspensions and estuarine sediments.* Applied and Environmental Microbiology, v.53, p.1365-1369.